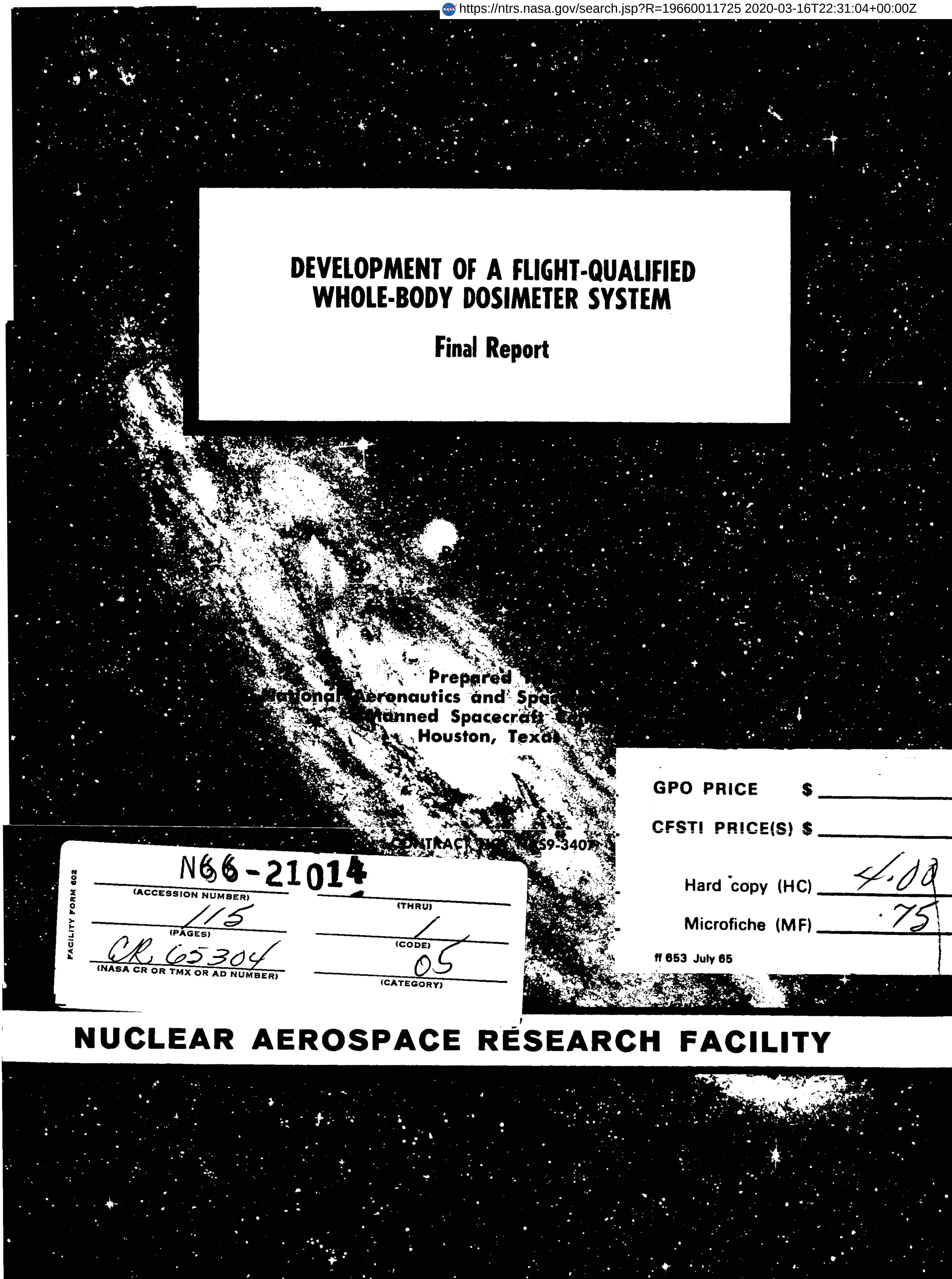

DEVELOPMENT OF A FLIGHT-QUALIFIED WHOLE-BODY DOSIMETER SYSTEM

Final Report

Prepared [illegible]
National Aeronautics and Spa[illegible]
Manned Spacecraft Ce[illegible]
Houston, Texas

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NUCLEAR AEROSPACE RESEARCH FACILITY

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DEVELOPMENT OF A FLIGHT-QUALIFIED WHOLE-BODY DOSIMETER SYSTEM

Final Report

R. Wiley

C. L. Fletcher

Prepared for
National Aeronautics and Space Administration
Manned Spacecraft Center
Houston, Texas

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GENERAL DYNAMICS | FORT WORTH

FOREWORD

The work reported in this document was performed at the Nuclear Aerospace Research Facility (NARF), General Dynamics/ Fort Worth, for the Manned Spacecraft Center of the National Aeronautics and Space Administration under contract NAS9-3407, Development of a Flight-Qualified Whole-Body Dosimeter System. The work was administered under the technical direction of the Radiation and Fields Branch, Advanced Spacecraft Technology Division of the Manned Spacecraft Center, with Mr. Robert Richmond acting as project manager.

Among those who have made contributions to this program are:

C. L. Fletcher	– electronic design, environmental testing, and calibration
R. M. Hall	– ionization chamber and system-packaging design, construction, and calibration
E. C. Harmon	– reliability analysis
R. G. Longley	– ionization chamber design, construction, calibration, and evaluation of ionization-chamber readout header
G. R. Smith	– electronic construction
R. Wiley	– project leader

ABSTRACT

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The development and construction of a whole-body dosimeter system for monitoring the radiation exposure to crew members during space missions is described. The system is a flight-qualified, self-contained unit consisting of a 6.8-cc ion chamber, electrometer, and electronics to drive a three-hand readout register. The system is capable of reading 0-1000 rad in 0.01-rad increments at a maximum rate of 108 rad/hr. The system weighs 0.8 lb, has a volume of 18.3 in.^{3}, and is contour shaped for compactness and easy handling. Construction details of the system, reliability estimates, qualifying tests, and operating instructions are given.

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I. INTRODUCTION

The Manned Spacecraft Center of the National Aeronautics and Space Administration (NASA) is developing a dosimeter system for measuring whole-body radiation dose to personnel during manned space missions. The work described here is in support of that effort, and is a continuation of developmental work performed under contract NAS9-992.

The principal effort in this work has been directed toward reducing the size, weight, and complexity of the prototypical dosimeter systems (Ref.1) developed under contract NAS9-992. Major design changes incorporated in the Flight-Qualified Whole-body Dosimeter System include (1) elimination of the depth-dose shield, (2) replacement of the electrical readout with an impulse register, and (3) a substantial reduction in weight and size of the system.

An additional task of evaluating a quartz-fiber electrometer assembly, built by Electro-Optical Systems, Inc., was also performed as part of this work.

Section II of this report describes the design and construction of the dosimeter system; Section III discusses reliability of the system; Section IV describes testing and calibration and Section V gives operating instructions. Detailed environmental-test requirements and the test results are presented in Appendix A and Appendix B, respectively. Appendix C is an evaluation study of the electrometer assembly manufactured by Electro-Optical Systems, Inc., and Appendix D lists the electrical and mechanical drawings furnished to the Manned Spacecraft Center.

II. DESCRIPTION OF SYSTEM

2.1 System Design

The radiation dosimeter system (Fig. 1) consists of a 6.8-cc ionization chamber, electronics, a self-contained battery power supply with a life of 250 hr, and a visual real-time readout register — all of which are integrated into a fiberglass and styrofoam package. The system occupies 18.3 in.^{3} and weighs 0.8 lb. The range of the dosimeter is 0-1000 rad (in 0.01-rad increments) with a maximum pulse rate of 3 pulses/sec, or 0.03 rad/sec. The maximum pulse rate corresponds to a dose rate of 108 rad/hr. The dosimeter system has been demonstrated to be flight-qualified by successfully passing the environmental tests as defined by Appendix A.

2.2 Principle of Operation

Dose is measured in terms of the current from the ionization chamber at the grid of electrometer tube V_1 (Fig. 2) by capacitor C_1. As C_1 acquires charge, the grid of V_1 becomes increasingly positive, causing the plate voltage to drop. Transistor Q_1 prevents loading of the plate circuit of V_1 and provides positive dc feedback to the screen grid of V_1, thereby increasing the gain of V_1. Q_1 also provides the necessary

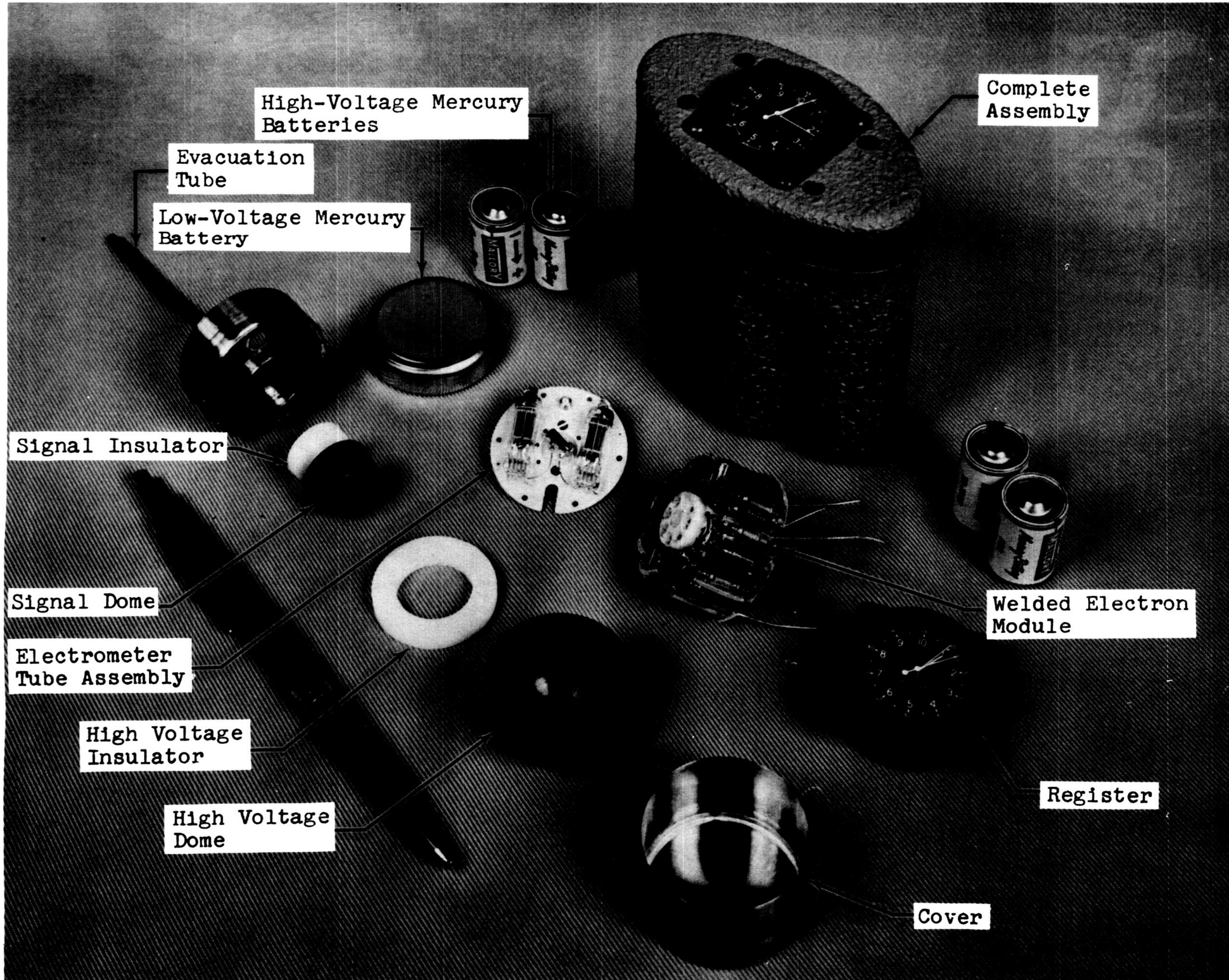

Figure 1 Flight-Qualified Whole-Body Dosimeter System - Complete Assembly and Components

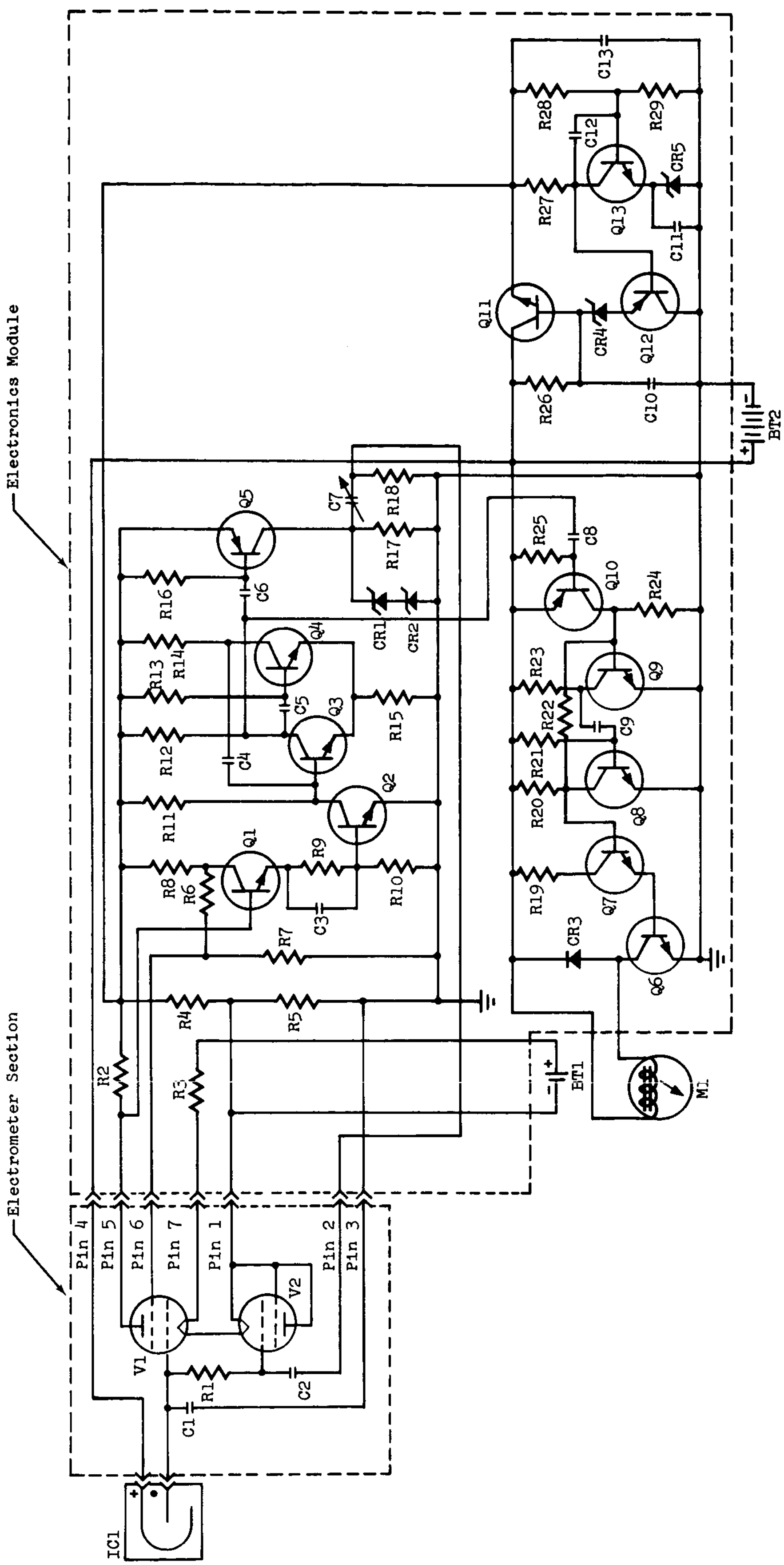

Figure 2 Dosimeter Electronics

drive for Q_2 which remains saturated and prevents the astable multivibrator (Q_3 and Q_4) from free-running when the plate voltage on V_1 is high (nominally 16 v). The astable multivibrator drives Q_5 into conduction, thus generating a feedback pulse of relatively constant width and amplitude. The feedback pulse is coupled through C_7 and C_2 to the grid of V_2 which conducts on the positive leading edge of the pulse and allows C_2 to acquire charge. However, V_2 does not conduct on the negative trailing edge of the feedback pulse, and the charge left on C_2 is distributed in the C_1, C_2, R_1, and R_{19} circuit. This results in a neutralization of the charge acquired by C_1 from the ionization chamber, permitting the grid of V_1 to become more negative and the plate voltage to become more positive. As the plate of V_1 becomes positive, Q_2 begins to conduct and gates off the astable multivibrator after one feedback pulse, resulting in the circuit being "reset." The astable multivibrator (Q_3 and Q_4) also drives Q_{10} into conduction, which in turn operates the monostable multivibrator (Q_8 and Q_9). The output pulse from the monostable multivibrator then drives Q_6 and Q_7 into conduction, which in turn steps the register.

2.3 Ionization-Chamber – Electrometer-Tube Assembly

2.3.1 Design of Ionization Chamber

In the Apollo dosimeter system it is desired to have an ion chamber of negligible weight, low operating voltage, and maximum signal output. The dimension of the outer electrode, the operating high voltage, the type of gas, and the saturation efficiency at a maximum dose rate were fixed early in the design. With these design factors established, the remaining variables were filling pressure and the dimension of the inner electrode. The dimension of the inner electrode affects both the chamber volume and field strength in the cavity, while the pressure affects the ion mobility. These variables were uniquely determined by the requirement for maximum signal output.

The shape selected for the ion-chamber electrodes is hemispherical. For spherical electrodes (Ref. 2),

$$\frac{6}{f}(1-f)^{\frac{1}{2}} = \left[1 + \frac{R}{r} + \frac{R^2}{r^2}\right]\left[\frac{2a}{3ek_1k_2}\right]^{\frac{1}{2}}\left[\frac{(R-r)^2\ (q)^{\frac{1}{2}}}{V}\right]$$

where

f = collection efficiency (a constant)

R = inner radius of the high-voltage electrode (a constant)

r = radius of inner electrode (a design variable)

a = volume recombination coefficient (a constant over the pressure range of interest)

e = charge per ion (a constant)

k_1 & k_2 = ion mobilities, inversely proportional to pressure (a design variable)

V = chamber high voltage

q = charge per unit volume per unit time, proportional to dose rate (a constant) and pressure (a design variable)

Grouping all constants and solving for pressure in terms of r gives

$$P = k' \left[\frac{1}{(R-r)^2 \; 1 + \frac{R}{r} + \frac{R^2}{R^2}} \right]^{2/3}$$

The ionization chamber current is given by

$$I = k''DvP$$

where D is the dose rate, v is the volume, and P is the pressure. In terms of radius r

$$I = k(R^3 - r^3) \left[\frac{1}{(R-r)^2 \; (1 + \frac{R}{r} + \frac{R^2}{r^2})} \right]^{2/3}$$

Let X = r/R, then

$$I = k(1-X^3) \left[\frac{X^2}{(1-X)^2 \; (1 + X + X^2)} \right]^{2/3}$$

The maximum operable dose rate is determined by the recycling time of the readout. Thus, the maximum dose rate for the system is 108 rad/hr. The high voltage was limited to 16 v so that it could be obtained from batteries and without the use of a dc converter. The saturation efficiency of 0.95 at the maximum dose rate was arbitrarily selected. Saturation data for r/R or X = 0.4 and for a pressure of 1 atm of ethylene at a dose rate of 108 rad/hr is listed below:

High Voltage (v)	Relative Current (amp)
+ 2	0.30
5	0.63
10	0.89
15	0.95
20	0.98
30	0.99
67	1.00
90	1.00

It was found that methane gas had similar saturation characteristics when the pressure was adjusted to give the same electron density (or current output) as ethylene.

The current and pressure as a function of X, computed from the expressions above and normalized to the data obtained for ethylene are shown in Figure 3. It can be seen from these data that some increase in current output can be obtained by

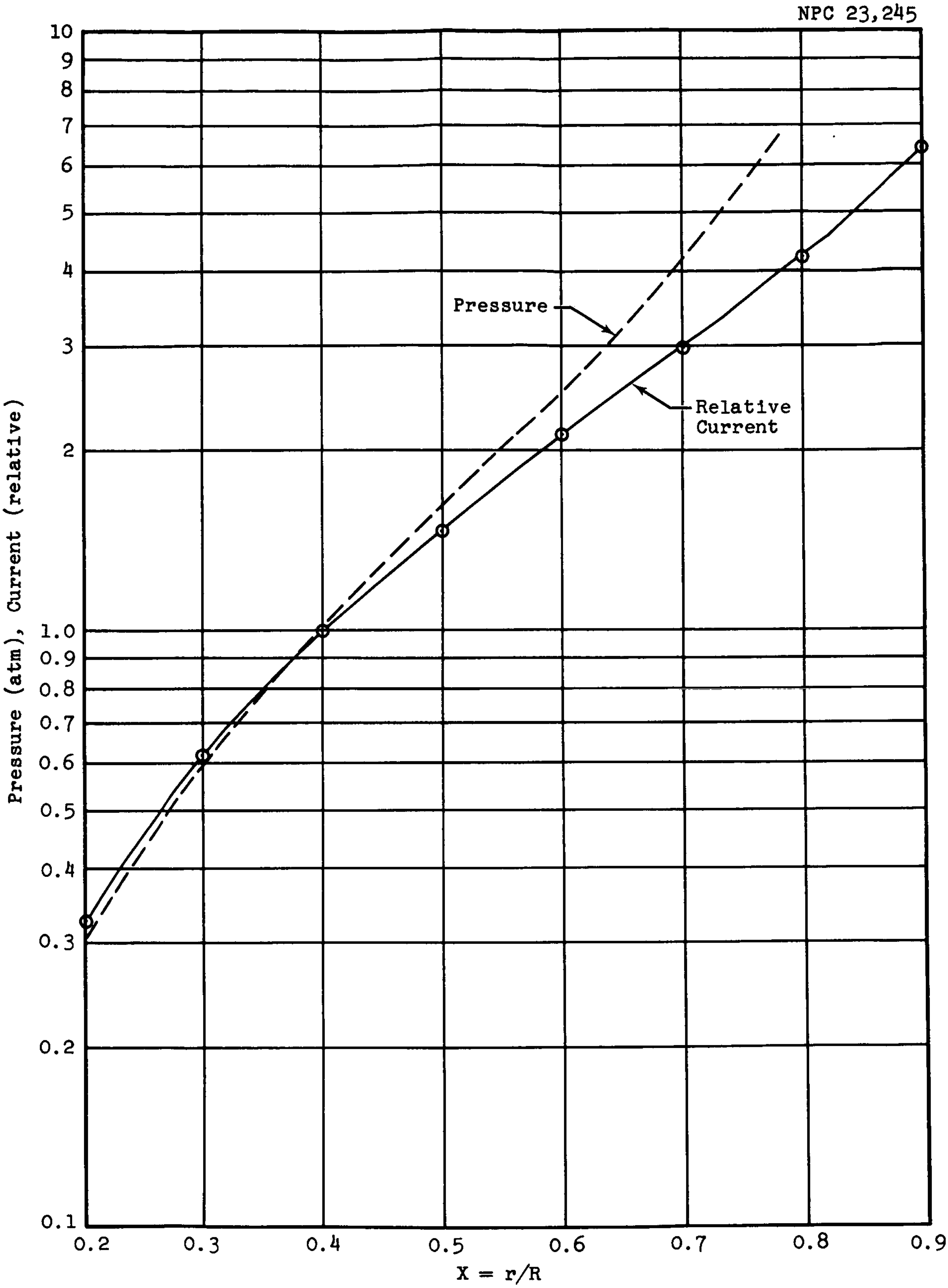

Figure 3 Ionization Chamber Current and Pressure as a Function of Electrode-Gap Relations

increasing the diameter of the inner electrode and increasing the pressure. For small electrode spacings, however, the pressure becomes unreasonably large. In the final ionization chamber design an X = 0.6 and a pressure of 2 atm of ethylene were selected so that the saturation efficiency at the maximum count rate (108 rad/hr) is greater than 0.95. If it is necessary to operate the chamber at higher dose rates for test purposes, an external high voltage should be used to obtain saturation.

2.3.2 Fabrication of Ionization Chamber

The front and sides of the ionization chamber case are made of 0.010-in. stainless steel. The high voltage electrode is made of 0.070-in.-thick tissue-equivalent plastic. The total thickness into the sensitive volume is about 0.4 gm/cm^2. High-density polyethylene insulators are used for both signal and high voltage. During evacuation, the chamber was baked at $80^{o}C$ to remove water vapor and outgas the plastic. Insulation resistance of the signal electrode was greater than 10^{15} Ω at 22 v, after filling and pinch-off of the filler tube.

2.3.3 Fabrication of Electrometer Tube Section

The electrometer tubes and high-resistance circuitry are mounted in a sealed, evacuated chamber which is an integral part of the stainless-steel ionization chamber case. High-voltage and signal connections are made with pins mounted in teflon insulators on the circuit board holding the electrometer tubes. The seven-pin header and electrical connections not on the circuit board are welded. Electrometer-tube leads are soldered directly to the circuit board and form the mechanical support for one end of the tube. The cold insulation resistance of the signal input was checked and found to be better than 10^{15} Ω at 22 v. After assembly the electrometer-tube chamber was baked at 70°C, evacuated to a pressure of less than 1 micron, and sealed off. The pressure may be expected to rise to several hundred microns over a period of time, because of outgasing of the printed-circuit card and polystyrene capacitors; however, this low pressure should not affect the sensitivity of the ionization chamber.

2.4 Electronics

2.4.1 High-Impedance Input Section

The high-impedance input section is contained in an evacuated compartment of the ionization-chamber case. The input to V_1 (Fig. 2) comes from the center electrode of the chamber through a glass-sealed feed-through. The insulation resistance of all leads and components in the grid circuit is kept as high as possible (10^{15} Ω) in order to keep the grid leakage to a minimum. The evacuated case was chosen, rather than potting compound, for several reasons. High insulation resistance is difficult to obtain with potting material, and the evacuated case gives RF shielding to the high-impedance input circuit.

The operation of the input section is as follows: Assume V_1 is cutoff and grid voltage is zero with respect to ground. Capacitor C_1 acts as the charge integrator. When C_1 is charged to approximately 2 v, V_1 is turned on and transistor Q_1 is turned off (see Section 2.4.2), starting a chain of events that results in a discreet pulse being fed back to pin 2 of the header. This pulse causes the grid of V_2 to go positive and grid current to neutralize the charge on C_1. Thus, V_1 is again cutoff and the circuit resumes the original static condition.

2.4.2 Control, Shaping, and Feedback Description

When V_1 (Fig. 2) is cut off, Q_1 is on and the base of Q_2 is positive. This clamps the collector of Q_2 near ground ($V_{ce\ sat}$) and disables the flip-flop. This is the static state with no ionization radiation. When V_1 turns on, the base of Q_1 drops and Q_1 is turned off, thus turning off Q_2. This allows the flip-flop to change state, feeding a pulse to the base of Q_5. Q_5 turns on hard and remains on for a time determined by C_6R_{16}. The series zeners, CR_1 and CR_2, clip the pulse at about 12.6 v. These temperature-compensated zeners eliminate variations in feedback caused by temperature extremes encountered by the system.

2.4.3 Astable Multivibrator — Register Driver

When the multivibrator changes state, the base of Q_{10} receives a negative pulse from the collector of Q_3. Q_{10} turns on, driving Q_9 on hard, thus upsetting the state of the astable circuit, causing Q_8 to turn off and the Darlington pair, composed of Q_6 and Q_7, to turn on. The Darlington stays on for a time determined by C_9R_{21}. The minimum time needed for the register to step is about 15 msec but for reliability reasons this was increased to at least 30 msec. When C_9 charges back to a slightly positive state, Q_8 will again turn on and the astable returns to its initial static state. CR_3 was added to eliminate the pulse due to the back emf of the coil when Q_6 is turned off.

2.4.4 Power Supply and Regulator

Power for the electronics is supplied by BT2 which is made up of four TR-114R mercury batteries. A voltage regulator is needed because of the change in battery output voltage resulting from temperature and decay changes. The unique feature of the method of voltage regulation used in this design is that the temperature change on CR5 cancels the temperature change of Q_{13}, thereby giving a temperature compensated output. CR5 and Q_{13} were chosen experimentally to give a regulated output with a $\Delta V_{out}/\Delta T^{o}C$ of 675 $\mu v/C^{o}$.

The output voltage is nominally 16 v but may vary slightly from that value because of the variation in the values of R_{28} and R_{29}. Values for R_{28} and R_{29} may be chosen to give any voltage required. The output voltage regulation characteristics will not be affected by slight variations in the values of R_{28} and R_{29}.

The regulated voltage feeds all circuits except the astable circuit and register.

The battery life is such that a 200 hr mission with a total dose of 1000R may be accomplished between battery changes.

Filament current to the two electrometer tubes is furnished by BT1, consisting of one RM-1438R mercury battery. Again, the mission time between battery changes is 200 hr or more.

2.5 Readout Register

The readout register is a modified "Accutron" watch manufactured by the Bulova Watch Company. This version utilizes a solenoid instead of the tuning fork arrangement to actuate the register. This modification changes the register from a timing device to an impulse counter. The register has 3 hands to indicate the integrated dose. The second-hand reads from 0.01 to 1 rad, the minute-hand from 1 rad to 100 rad, and the hour-hand from 100 to 1000 rad, a range of 10^5 pulses.

2.6 Electrical Connections

The hermitically-sealed high-impedance input unit plugs into the electronic module which contains the electrical components, including the variable capacitor C_7 (Fig. 2). Power connections to the electrometer tubes are made through the electronic module.

The ionization chamber is connected to the input unit by Micro-Dot Connectors.

The electrical connections from the electronics module to the readout register are made by 3 spring bars.

The electronics module is of welded-cordwood construction and is potted with Emerson and Cummings Stycast-1090SI potting compound.

III. RELIABILITY

3.1 General

The reliability prediction presented in this section is an estimate of the inherent reliability of the dosimeter system, i.e., the quality or degree of reliability which is built into the system through the use and control of such factors as

(1) Simplicity and soundness of design,

(2) Conservative application of reliable parts,

(3) Provisions for proper manufacturing techniques, and

(4) Adequate guidance and inspection during manufacture to ensure quality workmanship.

Because of the experimental nature of the ion chamber and the dial-type readout unit, sufficient test data are not available to establish a failure rate for these units. These units were, therefore, omitted from the reliability analysis with the concurrence of the N.A.S.A.

The batteries were also omitted from the analysis because they are expendable items which are replaced after each mission.

3.2 Summary

A reliability analysis was performed to determine the mean time between failure (MTBF) and, subsequently, the reliability of the Ion-Chamber Dosimeter System described in Section 2 of this report. Results of this analysis indicate an MTBF of approximately 248,000 hr.

During the environmental tests of the prototype unit, a seal failure occurred which resulted in the failure of the dosimeter to pass the humidity test. Tests were resumed after an improved seal was installed, and the dosimeter was qualified. A total operating time of 600 hr was accumulated on two dosimeter systems during this environmental test and the initial "burn-in" tests.

A reliability demonstration test was not required by N.A.S.A.; however, a philosophy of testing is submitted to show the feasibility of demonstrating a required reliability of a system of this type.

3.3 Failure Rate Assessment

The failure rate of each component part was determined by the use of data from MIL-HDB-217. The dosimeter circuit was reviewed to determine the voltage drop across each component or the wattage dissipated by each component during normal operation. A stress ratio was thus established for each part, i.e., the ratio of actual voltage to rated voltage, or actual wattage to rated wattage (as the case may be). After the stress ratio for each component had been calculated, the failure rates were obtained from the appropriate tables in MIL-HDB-217. These failure rates are presented in Table 1 in percent failures per 1,000 hr.

3.4 Reliability Analysis

The reliability model of the dosimeter system is an application of the product rule for computing reliability. All of the components are required to operate in order for the system to function properly; therefore, the components are in series and the reliability is

$$R_s = 1 - \int_o^T f(t)\ dt$$

$$= 1 - \int_o^T \exp\left(\sum_{i=1}^{n} \lambda_i\ t\right) dt$$

$$= \exp\left(\sum_{i=1}^{n} \lambda_i\ t\right)$$

where

R_s = probability that the time to first failure is greater than time T

t = units of time

N = number of system components

Table 1

COMPONENT FAILURE RATE APPORTIONMENT FOR
THE ION-CHAMBER DOSIMETER SYSTEM

Quant	Part Description	Rating	Voltage	Wattage	Unit* Failure Rate	Total* Failure Rate
1	Resistor, Comp.	1.5 M		.250	.001	.001
2	Resistor	2.7 M		.250	.001	.002
1	Resistor, Comp.	22 M		.250	.001	.001
1	Hi Resistance Paint	109		-	-	-
2	Transistor (Fairchild)	2N718A		1.2	.02	.04
8	Transistor (Fairchild)	2N2484		1.2	.02	.16
3	Transistor (Motorola)	2N3136		1.8	.02	.06
2	Zener (Fairchild)	FCT 1025		-	.01	.02
1	Zener (Motorola)	1N3606			.01	.01
2	Zener	1N4099			.01	.02

*Failure rate in % per thousand hours.
Mean Time Between Failure (MTBF) = 284,000 hr.

(Table continued)

Table 1 (Cont'd)

Quant	Part Description	Rating	Voltage	Wattage	Unit* Failure Rate	Total* Failure Rate
2	Capacitor, Polystyrene Type CPR (Centralab)	22 μμf	500		.001	.002
1	Capacitor Type 2002 (Potter)	51 μμf	200			.001
1	Capacitor, Type 2002 (Potter)	.01 μf	200			.001
1	Capacitor, Type 2002 (Potter)	.003 μf	100			.001
2	Capacitor, Tant. Type 1500, (Sprague)	.22 μf	35			.002
1	Capacitor, Tant. Type 1500, (Sprague)	.22 μf	50		.001	
1	Capacitor, Tant. Type 1500 (Sprague)	.47 μf	50			.001
1	Capacitor, Tant. Type 1500 (Sprague)	3.3 μf	50			.001
2	Capacitor, Tant. Type 1500, (Sprague)	4.7 μf	50			.002
1	Capacitor, Variable Type MC601Y (JFO)	1-14 μf	-			.001
1	Resistor, Comp.	39		.125	.001	.001
1	Resistor, Glass (Corning)	220		.25		.001
1	Resistor, Glass (Corning)	15 K		.25		.001

(Table continued)

Table 1 (Cont'd)

Quant	Part Description	Rating	Voltage	Wattage	Unit* Failure Rate	Total* Failure Rate
1	Resistor, Comp.	46.4 K		.125	.001	.001
2	Resistor, Glass (Corning)	46.4 K		.125	.001	.002
1	Resistor, Glass (Corning)	47 K		.125	.001	.001
1	Resistor, Glass (Corning)	56.2 K		.125	.001	.001
1	Resistor, Glass (Corning)	68 K		.250	.001	.001
4	Resistor, Glass (Corning)	100 K		.250	.001	.004
2	Resistor, Glass (T.I.)	178 K		.250	.001	.002
1	Resistor, Glass (T.I.)	180 K		.250	.001	.001
2	Resistor, Glass (T.I.)	220 K		.250	.001	.002
1	Resistor, Glass (T.I.)	464 K		.250	.001	.001
2	Resistor, Glass (T.I.)	470 K		.250	.001	.002
1	Resistor, Glass (T.I.)	562 K		.250	.001	.001
3	Resistor, Glass (T.I.)	681 K		.250	.001	.003
				TOTAL		.352

λ_i = failure rate of ith component

$i = 1, 2, 3, \ldots N$

Use of the above equation has been based on the assumption that the time to failure for the system is exponentially distributed, and that the failure rate is consequently constant. The above equation was used to derive the system reliability as a function of time in hours; the resultant curve is presented in Figure 4. The reliability curve indicates that the dosimeter system exhibits a very high inherent reliability; e.g., the probability that the time to the first failure will exceed 30,000 hr is 90%. Since the dosimeter is required to operate for approximately 200 hr, a reasonable reliability requirement would be .90 for a 200-hr mission. While it is not economically feasible to attempt to demonstrate an MTBF of 248,000 hr, it is logical to demonstrate the .90 reliability for a 200-hr mission. The significance of the high inherent reliability derived by this analysis is that the closer the true MTBF is to the estimated MTBF, the higher the probability of demonstrating a particular reliability.

3.5 Reliability Test Philosophy

Reliability testing of the dosimeter system was not required during its design, development, and fabrication; therefore,

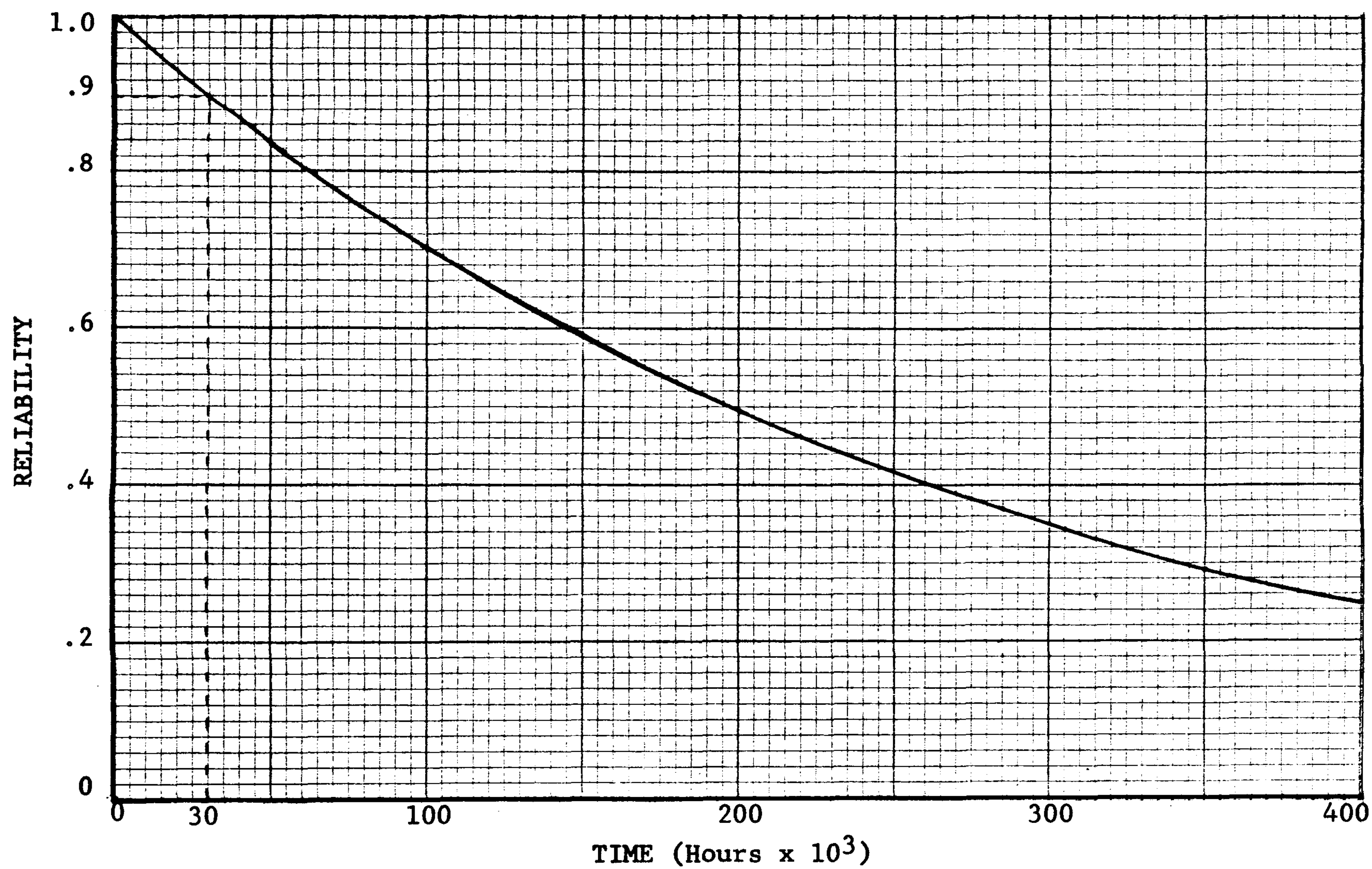

Figure 4 RELIABILITY CURVE FOR ION CHAMBER DOSIMETER SYSTEM

the reliability of the system was estimated analytically. In order to obtain a system with as high an inherent reliability as possible, piece parts and subassemblies were derated so that the stress on each part would be minimized.

During the 100-hr "burn-in" and environmental tests on the first prototype, and during the 100-hr "burn-in" test on the second unit, operating time and failure data were recorded. During these tests, a total of 600 hr of operating time was accumulated on two dosimeters. One primary failure was noted during the humidity test. This failure, caused by a faulty seal, resulted in the deterioration of the batteries and the readout mechanism, and subsequent stoppage of system operation. These parts were replaced, an improved seal was installed, and the environmental test was completed with no additional malfunctions.

In a realistic reliability test to demonstrate a minimum reliability of 90% for a 200-hr mission, the dosimeter would be required to exhibit an MTBF of approximately 2,000 hr. In view of the high estimated reliability of the system, the 2,000-hr MTBF could be demonstrated in a minimum time with a small sample size. For example, if the true MTBF were only 20,000 hr, a 2,000-hr MTBF could be demonstrated by testing a sample of 12 units for 200 hr and considering that 0.90 reliability had been demonstrated with 90% confidence if no more than one failure occurred. The probability of passing this particular test would also be 90%.

In the above reliability test procedure, consideration was not given to cost of the test samples nor to the cost per hour of test time. In a final test plan for the type system described in this report, these costs would be an important consideration in selecting the type of reliability test that would be conducted.

3.6 Conclusions

The main conclusion drawn from this reliability analysis is that the dosimeter system exhibits a high inherent reliability as a result of the judicious selection of piece parts and conservative design. It is further concluded that a reasonable value of reliability could be demonstrated by the use of a few additional samples in a minimum amount of time.

IV. TESTS AND CALIBRATION

4.1 Environmental Tests

One of the developed dosimeter systems was subjected to, and passed, the environmental condition as specified in Appendix A. All of the environmental tests except for the rain test were performed at Garwood Laboratories, Inc., Montebello, California. The results of the environmental tests conducted by Garwood are given in Appendix B. The results of rain test are given below.

The dosimeter system was sprayed with a garden hose for 20 min on each side. No physical damage was observed and the unit operated satisfactorily after the test was completed.

Prior to delivery, the dosimeter systems were operated continuously for 100 hr as part of the reliability program.

4.2 Calibration

Calibration of the dose system was performed with a Co^{60} source. The source was calibrated in r/hr by N.B.S. This was converted to tissue rad on the basis of 94.3 ergs/gm equivalent to one r.

Since it is necessary to calibrate with the source near the detector, a center of detection was determined experimentally for the range of source separations used. The center of detection was found to be 2 cm back from the ion-chamber end of the unit.

Calibration is simply a matter of adjusting the feedback capacitor (C_7 in Fig. 2) to obtain 10 mrad of dose per step of the readout.

The sensitivity to a PuBe neutron source was measured on the two systems and it was found that 93 mrem of neutron is equivalent to 10 mrad (tissue).

V. OPERATING INSTRUCTIONS

The dosimeter systems are delivered in a non-operative condition, i.e., the battery power supplies (4 ea TR-114R and 1 ea RM-1438R) must be installed to make the systems operative. Instructions for installing the batteries are given below.

(1) Unfasten the 4 screws on the lid of the system package and remove the lid. Note that the package contains 3 cylindrical compartments: a large center compartment that houses the filament battery (RM-1438R), and 2 small compartments that house the high-voltage batteries (TR-114R).

(2) Place 2 TR-114R batteries in series in the compartment marked "+", so that the positive terminal of the battery mates with the brass tab in the bottom of the compartment.

(3) Place the 2 remaining TR-114R batteries in series in the compartment marked "-", so that the negative terminal mates with the brass tab in the bottom of the compartment.

(4) Place the filament battery (RM-1438R) in the center compartment so that its negative terminal is in contact with the electronics module.

(5) Place polyethylene spacer on top of the filament battery.

(6) Replace the package lid so that the 3 copper contacts on the bottom of the lid make contact with the spring bars mounted on the periphery of the center compartment.

(7) Insert and tighten lid screws (the system is now operative).

Note: The readout-register reset is located on the backside of register, therefore it is necessary to remove the package lid to zero the register.

APPENDIX A

ENVIRONMENTAL TESTING REQUIREMENTS

(Note: The specifications for environmental testing outlined in this appendix have been reproduced, without change, from Appendix 1. of Contract NAS9-3407)

APPENDIX A

ENVIRONMENTAL TESTING REQUIREMENTS

Reference: (b) "General Environmental Requirements for Model 133P" — McDonnel Aircraft Corporation Report 8433 dated November 20, 1961 as revised on January 19, 1962, June 20, 1962 and October 15, 1963.

1. High Temperature

MIL-E-5272, Procedure II except chamber pressure shall be maintained at 5.5 $\pm$ .4 psia and the equipment shall operate continuously during the test.

2. Decompression

The equipment shall be placed in a chamber and the pressure reduced to 1.47×10^{-5} psia. The equipment shall operate satisfactorily with the chamber temperature at 160°F for 1.5 hours. There shall be no crushing, distortion, opening of seals, or other damage deleterious to the proper operation, life and serviceability of the equipment as a result of this test. Temperatures are average test chamber wall temperature.

3. Low Temperatures

Equipment temperatures shall be recorded during these tests. Equipment which will be mounted on a cold plate in the spacecraft may be mounted on a cold plate during this test. The cold plate shall be maintained at a temperature of 40°F ± 10°, shall be no larger than the mounting base of the equipment, and shall have a heat storage capacity with zero flow equivalent to .080-inch-thick, 2024T4 aluminum. Equipment temperatures shall be recorded during these tests. Temperatures are average test chamber wall temperature. Table I Equipment as specified in Reference (b) — the equipment shall be placed within the test chamber and the chamber cooled to, and maintained at, a temperature of 0°F. The equipment shall be required to operate in this environment for a period of four hours.

4. Temperature-Pressure (Altitude)

The equipment shall be placed within the test chamber and the chamber pressure reduced to 1.47×10^{-5} psia. The equipment shall be operated at rated load while the chamber is raised to 160°F. The chamber temperature shall then be lowered to 0°F in 45 minutes and raised again to 160°F in 45 minutes to constitute one cycle. Five more cycles shall be completed with the equipment operating. The pressure and temperature shall then be returned to room ambient with the equipment operating.

5. Humidity

MIL-E-5272-C Procedure 1.

6. Rain

The test article shall be sprayed with a garden hose for 20 minutes on each of the six sides.

7. Sand and Dust

MIL-E-5272-C, Procedure I and Salt Spray.

8. Oxygen Atmosphere

Table I equipment as specified in reference (b) shall be placed in an atmosphere of 100% oxygen. The ambient pressure shall be maintained at 5.5 $\pm$ .4 psia. The equipment shall be operated the 40-hour duration of the test. Performance, obnoxious odors, or deterioration of seals or lubricants during the test shall constitute failure to pass this test. For at least two hours during this test, the ambient temperature shall be maintained at 160°F.

> The requirements of this test will be satisfied by performing the High Temperature Test of para 1 in 100% oxygen atmosphere.

9. Explosive Atmosphere

The equipment shall be placed inside an explosion chamber as specified in para 4.13.3 of MIL-E-5272C. A mixture of aviation gasoline and air will be used as the explosive mixture. The test shall be conducted in accordance with Procedure III of MIL-E-52720, except:

1. Only those external covers which are normally removable in field usage shall be removed.

2. Test shall be accomplished only at simulated local ground level altitude.

10. Shock

All shock tests shall be a half-sine-wave pulse of 11 $\pm$ 1 millisecond duration.

11. Acceleration

Launch — 1.0 g to 7.25 g, increasing linearly in 326 seconds. Abort — 7.25 g for 1 sec, each of 3 axes. Re-entry — 15.7 g for 30 sec, each of 3 axes.

12. Vibration

Nonoperating — Frequency sweep 5 to 2 kc and back to 5 in 15 minutes, 2 cycles. Amplitudes — Fig. 1 or 2 of reference (b). Vibration — 10 min each resonant frequancy noted in sweep. Tests to be conducted in each of 3 axes.

Operating — Same as above.

Random Vibration — Figure 3 curve I of reference (b), 15 min duration. Each of three axes.

Random Vibration — Same as above Curves I, II, or III as specified in equipment SCD.

13. Acoustic Noise

Equipment Operating: The equipment shall operate within

SCD tolerances while subjected to an overall sound pressure level with the distribution as indicated in Figure 4 of reference (b). The test duration shall be 30 minutes distributed in three (3) most sensitive mutually perpendicular directions equally for 10 minutes per orientation. If the power of the available facility is not sufficient to perform the entire wide band tests, the spectra may be divided, with the approval of the NASA Manned Spacecraft Center into a maximum of 4 bands with 30 minutes testing in each band.

Equipment Monoperating: Repeat the above test.

14. Radio Interference

Equipment shall be tested for generation and susceptability to radio interference in accordance with MIL-I-26600; however, changes to the equipment to permit meeting these requirements shall be in accordance with the requirements of the particular SCD involved.

APPENDIX B

GARWOOD LABORATORIES, INC., ENVIRONMENTAL TEST REPORT

(*Note*: This report of test results has been reproduced from masters furnished by the testing contractor)

GARWOOD LABORATORIES, INC.
708 SOUTH VAIL AVE.
MONTEBELLO, CALIF.

REPORT NO. 3161

TEST REPORT

July 7, 1965

REPORT NO. 3161
ENVIRONMENTAL TESTS ON
GENERAL DYNAMICS/FORT WORTH
ION CHAMBER DOSIMETER SYSTEM
TO McDONNELL REPORT 8433

Mfg. By: General Dynamics/Fort Worth
Fort Worth, Texas

Test By: A.B. Judd, J. Siegel	Concurred:
Report By: C.F. Myers	

County of Los Angeles
State of California } ss.

J. L. Garwood, being first duly sworn, deposes and says: that the information contained in this report has been obtained as the result of complete and carefully conducted tests, and is to the best of his knowledge and belief, true and correct in all respects.

Subscribed and sworn to before me on this 9th day of July 1965.

Notary in and for said County and State
Elsie J. Shepard
My Commission expires ... 19...

J. L. Garwood, Mechanical Engineer

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1. REFERENCES

Abbreviated Form	Full Reference Description
P.O. 150897	Purchase Order No. 150897 dated 2-22-65 from General Dynamics/Fort Worth
RPT 8433	General Environmental Requirements for Model 133P, McDonnell Aircraft Corporation Report 8433, Revision C, dated 10-15-63.
MIL-I-26600	Military Specification MIL-I-26600 (USAF) dated 2 June 1958: Interference Control Requirements, Aeronautical Equipment.
MIL-E-5272C	Military Specification MIL-E-5272C(1), dated 20 January 1960: Environmental Testing, Aeronautical and Associated Equipment, General Specification For.

2. DESCRIPTION OF UNIT TESTED

The unit submitted for test was one (1) Ion Chamber Dosimeter System designed and fabricated by General Dynamics/Fort Worth. The unit was incased in an insulated housing and was battery operated. The unit was portable and was designed to measure and register the intensity of radiation when placed within a radio-active field. The approximate weight of the unit was 1.0 lb. The approximate physical dimensions of the unit were 3.0 in x 3.0 in x 1-3/4 in.

3. PURPOSE

The purpose of this test program was to subject the unit to the following tests of RPT 8433 and MIL-E-5272C:

Test	RPT 8433 Para.	MIL-E-5272C Para.
High Temperature*	4.2.1 Modified	4.1.2, Proc. II Modified
Decompression*	4.2.2 Modified	- - -
Low Temperature*	4.3.1	- - -
Temperature-Pressure*	4.5 Modified	- - -
Humidity	4.6	4.4.1, Proc. I
Salt Spray	4.8	4.6.1, Proc. I Modified
Sand and Dust	4.9	4.11.1, Proc. I
Oxygen Atmosphere*	4.11	- - -
Explosive Atmosphere*	4.12 Modified	4.13.4, Proc. III Modified
Acceleration	4.14 Modified	- - -

3. PURPOSE (Cont'd)

Test	RPT 8433 Para.	MIL-E-5272C Para.
Vibration	4.15 Modified	- - -
Acoustic Noise*	4.16.1, Fig.4	- - -
Radio Interference*	4.18	- - -
Shock	- - -	4.15.5, Proc.V

*The unit was to be operating during these tests.

4. CONCLUSIONS

The unit was subjected to the tests as required. Examination disclosed no deterioration, damage or change in performance which could in any manner prevent the unit from meeting functional, maintenance or service requirements during service life. See Para. 5.5.3. The unit was considered to have passed the test program as conducted in this Laboratory and was returned to the manufacturer.

5. TEST METHODS AND RESULTS

5.1 HIGH TEMPERATURE TEST

5.1.1 Requirements -- RPT 8433, Para. 4.2.1 (Modified)
MIL-E-5272C, Para. 4.1.2, Proc. II (Modified)

5.1.2 Methods -- The operating unit was placed in a temperature-altitude chamber which contained an observation window for visually monitoring the unit for damage or deterioration during the test. The chamber was sealed and the internal temperature was increased to $+160^{\circ}F$. After temperature stabilization, the pressure within the chamber was reduced to 5.5±.4 PSIA. These conditions were maintained for a period of 48 hours. During this time period the unit was periodically monitored for damage or deterioration. At the conclusion of the test period, the unit was returned to room ambient conditions and visually examined for damage. The unit was then exposed to a Cobalt-60 nuclear radiation source (1.9 millicurie activity) for functional check-out.

5.1.3 Results -- Examination of the unit during and after the test period disclosed no visible evidence of damage or deterioration. The unit operated normally when exposed to the Co^{60} radiation source. There was no damage deleterious to the proper operation, life or serviceability of the unit as a result of the test conditions. The unit was considered to have passed the High Temperature Test as conducted in this Laboratory.

5.2 DECOMPRESSION TEST

5.2.1 Requirements -- RPT 8433, Para. 4.2.2. (Modified)

5.2.2 Methods -- The operating unit was placed in a bell jar type vacuum system. The internal temperature was increased to +160°F by heat lamps installed around the chamber. The chamber temperature was controlled and monitored by a thermocouple junction placed near the test unit. After temperature stabilization, the chamber pressure was decreased to 1.47×10^{-5} PSIA. These conditions were maintained for a period of 1.5 hours. At the conclusion of the test period, the unit was returned to room ambient conditions and removed from the chamber.

5.2.3 Results -- At the completion of the test, the unit was examined. There was no evidence of crushing, distortion, opening of seals or damage. The unit operated without hesitation when exposed to the Co^{60} radiation source. The unit was considered to have passed that portion of the test to which it was subjected in this Laboratory.

5.3 LOW TEMPERATURE TEST

5.3.1 Requirements -- RPT 8433, Para. 4.3.1

5.3.2 Methods - - The operating unit was placed in a low temperature chamber. A thermocouple junction was installed on the unit to monitor unit temperature during the test. Thermocouple connections were made through a penetration port in the chamber wall. The test chamber temperature was lowered to 0°F. After temperature stabilization, as indicated by the thermocouple junction installed on the unit, the temperature conditions were maintained for a period of 4 hours. Temperature stabilization was defined as the unit temperature of 0°F remaining unchanged for a period of 30 minutes.

5.3.3 Results -- Following the test, the unit was removed from the chamber and examined. There was no visible damage or degradation of the unit resulting from the test conditions. The test unit operated normally when exposed to the Co^{60} radiation source. The unit was considered to have passed the Low Temperature Test as conducted in this Laboratory.

5.4 TEMPERATURE-PRESSURE TEST

5.4.1 Requirements -- RPT 8433, Para. 4.5 (Modified)

5.4.2 Methods -- The operating unit was placed in a vacuum chamber with heat lamps arranged as described in Para. 5.2.2. A cooling coil was installed around the unit with connections made through penetration ports in the chamber base. The cooling coil was connected to an LN_2 source with a solenoid operated valve in the line to control the flow. A thermocouple junction was placed near the unit and was connected to a temperature programmer which regulated the chamber temperature by controlling the heat lamps and LN_2 flow. The chamber was then sealed and the internal pressure was decreased to 1.47×10^{-5} PSIA. The chamber temperature was stabilized at $+160^{\circ}F$. The chamber temperature was lowered to $0^{\circ}F$ in 45 minutes, then returned to $+160^{\circ}F$ in 45 minutes at a linear rate to constitute one cycle. The unit was subjected to 5 additional temperature cycles for a total of 6 cycles with the above chamber pressure being maintained. At the conclusion of the last temperature cycle, the chamber was returned to room ambient. Following this, the operating unit was removed from the chamber and examined.

5.4.3 Results -- Examination of the unit, following the test, disclosed no damage or deterioration as a result of the test conditions. The unit operated without hesitation when exposed to the Co^{60} radiation source. The unit was considered to have passed the Temperature-Pressure Test as conducted in this Laboratory.

5.5 HUMIDITY TEST

5.5.1 Requirements -- RPT 8433, Para. 4.6
MIL-E-5272C, Para. 4.4.1, Proc. I

5.5.2 Methods -- The test specimen was placed in a humidity chamber. See Photo 1. The temperature in the chamber was raised from room temperature, approximately 76°F, to 160°F during a 2 hour period. The temperature of 160°F was then maintained for a 6 hour period. Following this, the temperature of the chamber was decreased over a 16 hour period to 76°F. A relative humidity of 95% was maintained throughout the complete cycle. This cycle was repeated for a total of 240 hours or a 10 day period. Distilled water having a pH value between 6.5 and 7.5 at 77°F was used to obtain the required humidity.

5.5.3 Results -- Examination following the test disclosed corrosion on the assembly screws and moisture within the register of the unit. The unit would not operate when exposed to the Co^{60} radiation source. The unit was disassembled. Corrosion was found on the batteries and on the internal components of the register. The unit was returned to the manufacturer for evaluation. Upon resubmittal for test, it was noted that the unit was assembled with stainless steel screws with plastic covers and the seal was improved. The above test was then repeated. At the conclusion of the test period, the unit was examined. There was no visible deterioration or corrosion which would prevent the equipment from meeting operational and maintenance requirements during its service life. The sample was considered to have passed the portion of the test to which it was subjected in this Laboratory.

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5.6 SALT SPRAY TEST

5.6.1 Requirements -- RPT 8433, Para. 4.8
MIL-E-5272C Para. 4.6.1, Proc. I (Modified)

5.6.2 Methods -- The specimen, was suspended in a salt spray test chamber. Interior parts of the chamber were constructed of materials which would not affect the corrosiveness of the salt fog. A salt solution consisting of sodium chloride with less than 0.1% sodium iodide and less than 0.2% total impurities on the dry basis was prepared by dissolving 20 ± 2 parts by weight of salt in 80 parts by weight of distilled water. This solution was atomized into the chamber by passing clean compressed air with a relative humidity of at least 85% through a plastic atomizer. Air was humidified prior to entry into the chamber by passing it through a chamber of water maintained at a temperature in excess of 95°F. Fog from the atomizer was directed into the chamber so there was no direct impinging of spray on the specimen. The salt solution was kept free from solids by filtration. Specific gravity and pH were maintained at 1.126 to 1.157 and 6.5 to 7.2 respectively when measured at a temperature of 92°F to 97°F. The pH of the solution was controlled by c.p. hydrochloric acid. Temperature of the exposure zone was maintained at 95 ±2°F. Flow of fog from the atomizer was such that a receptacle having a horizontal surface area of 80 square centimeters would collect 0.5 to 3.0 cc. of solution per hour anywhere in the exposure zone. The specimen was exposed in this environment for 50 hours. Upon removal, the unit was washed off with warm water to remove salt deposits.

5.6.3 Results -- At the conclusion of the test, the unit was examined. There was no visible deterioration or corrosion which would prevent the equipment from meeting operational and maintenance requirements during its service life. The sample was considered to have passed the portion of the test to which it was subjected in this Laboratory.

5.7 SAND AND DUST TEST

5.7.1 Requirements -- RPT 8433, Para. 4.9
MIL-E-5272C, Para. 4.11.1, Proc. I

5.7.2 Methods -- The unit was suspended in the center of the air stream passing through a sand and dust machine. Sand and dust of the specified composition was introduced into the moving air stream in sufficient quantity to maintain a density of 0.1 to 0.5 grams per cubic foot within the test space. The velocity of the sand and dust particles was 100 to 500 feet per minute. Relative humidity in the chamber was maintained below 30% during the test. The internal temperature of the chamber was stabilized at 77°F. The test unit was subjected to these conditions for a period of 6 hours. The temperature inside the test chamber was then raised to 160°F, and the conditions above were maintained for an additional 6 hours.

5.7.3 Results -- At the completion of the test period, the unit was removed from the test chamber and examined. The unit was well covered with sand and dust. The excess of contaminants was removed. There was no visible deterioration which would prevent the equipment from meeting operational and maintenance requirements during its service life. The unit operated normally when exposed to the Co^{60} radiation source. The unit was considered to have passed that portion of the test to which it was subjected in this Laboratory.

5.8 OXYGEN ATMOSPHERE TEST

5.8.1 Requirements -- RPT 8433, Para. 4.11

5.8.2 Methods -- The operating unit was placed in a bell jar type vacuum chamber. Thermocouple and heat lamp arrangement was as described in Para. 5.2.2. The internal pressure of the chamber was reduced to 5.5 ± .4 PSIA using a vacuum pump designed for oxygen service. Oxygen was continuously bled into the vacuum chamber at a slow rate during the test to insure a 100% oxygen atmosphere. These conditions were maintained for a period of 40 hours with the temperature increased to +160°F during the last two hours of the test.

5.8.3 Results -- At the conclusion of the test, the unit was examined. There was no evidence of damage, deterioration or obnoxious odors resulting from the test conditions. The unit operated normally when exposed to the Co^{60} radiation source. The test unit was considered to have passed the Oxygen Atmosphere Test as conducted in this Laboratory.

5.9. EXPLOSIVE ATMOSPHERE TEST

5.9.1 Requirements -- RPT 8433, Para. 4.12 (Modified)
MIL-E-5272C, Para. 4.13.3&.4, Proc. III (Modified)

5.9.2 Methods

5.9.2.1 The operating unit was installed in a test chamber equal to MIL-C-9435. The chamber was sealed and the ambient temperature within the chamber was raised to +160 ±5°F. The temperature of the test unit and the chamber walls was allowed to rise to within 20°F of the chamber air prior to the introduction of the explosive mixture.

5.9.2.2 The internal test chamber pressure was reduced to an altitude approximately 10,000 feet above the desired test altitude (station level). The weight of fuel (gasoline, grade 100/130) necessary to produce an air-fuel ratio of 13 to 1 at the test ambient was drawn into the chamber. A time of 3 ± 1 minutes was allowed for introduction and vaporization of the fuel. Air was admitted into the chamber until the simulated altitude was 5000 feet above station level. At this time, the explosiveness of the air-fuel mixture was verified by sampling and exploding the sample vapor.

5.9.2.3 With the unit operating continuously, air was then admitted steadily into the chamber until station level was reached. At this time, the explosiveness of the air-fuel mixture was again verified by sampling and exploding the sample vapor.

5.9.3 Results -- At no time was there an explosion in the chamber as a result of the operation of the test unit. The samples of the air-fuel mixture were found to be explosive in each case. There was no malfunction of the unit evident during the test. The unit operated normally when exposed to the Co^{60} radiation source following the test. The unit was considered to have passed the Explosive Atmosphere Test as conducted in this Laboratory.

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5.10 ACCELERATION TEST

5.10.1 Requirements -- RPT 8433, Para. 4.14 (Modified)

5.10.2 Methods

5.10.2.1 Acceleration Specimen Axis Identification

X Axis -- Normal to the dial face
Y Axis -- Parallel to the short dimension
Z Axis -- Mutually perpendicular to the X and Y Axes

5.10.2.2 Conduct of Test -- The unit was installed in a clamp type fixture. This assembly was then secured on the table of the centrifuge boom. The acceleration force was increased from 1.0 G to 7.25G's at a linear rate in 326 seconds and maintained at this level for one second, then increased to 15.7 G's for 30 seconds. This test was conducted along each of three mutually perpendicular axes. Each axis extended in a radial direction with respect to the centrifuge center of rotation.

5.10.3 Results -- Following the test, the unit was visually examined. There was no evidence of structural failure, distortion or damage. The unit operated normally when exposed to the Co^{60} radiation source. The unit was considered to have passed the Acceleration Test as conducted in this Laboratory.

5.11 VIBRATION TEST

5.11.1 Requirements -- RPT 8433, Para. 4.15 (Modified) Curve III

5.11.1.1 Vibration Test Outline -- The unit was to be vibrated using a random signal having a bandwidth from 20 to 2000 CPS. The constant spectral density was to be 0.065 G^2/CPS from 20 to 700 CPS and 0.020 G^2/CPS from 700 to 2000 CPS. The above level of vibration is 8.4 G's RMS as read on a true RMS voltmeter. The time duration was to be for 15 minutes along each of 3 mutually perpendicular axes for a total of 45 minutes. The test was to be conducted at room ambient conditions.

5.11.2 Methods

5.11.2.1 Vibration Specimen Axis Identification

X Axis -- Normal to the dial face
Y Axis -- Parallel to the short dimension
Z Axis -- Mutually perpendicular to the X and Y Axes

5.11.2.2 Vibration Test Mounting Method -- The unit was installed in a rigid clamp type fixture fabricated of magnesium tooling plate. This fixture was capable of transmitting the specified vibration alpng each of the unit's three mutually perpendicular axes.

5.11.3 Results -- The unit and vibration system were equalized to provide conformance with the random vibration spectrum outlined in Para. 5.11.1.1 above. After attainment of the required equalization, the unit was subjected to 15 minutes of random vibration at 8.4 G's RMS along each of 3 mutually perpendicular axes. The vibration schedule was in accordance with Para. 5.11.1.1.

At the conclusion of the test, the unit was examined. There was no visible evidence of structural failure or distortion as a result of the test conditions. The unit operated normally when exposed to the Co^{60} radiation source. The unit was considered to have passed the VibrationTest as conducted in this Laboratory.

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5.12 SHOCK TEST

5.12.1 Requirements -- RPT 8433, Para. 4.13 (Modified)
MIL-E-5272C, Para. 4.15.5.1, Proc. V

5.12.2 Methods

5.12.2.1 Shock Specimen Axis Identification

X Axis -- Normal to the dial face
Y Axis -- Parallel to the short dimension
Z Axis -- Mutually perpendicular to the X and Y Axes.

5.12.2.2 Conduct of Test -- The test unit was installed in a clamp type fixture as described in Para. 5.11.2.2. This assembly was installed on the table of a MIL-S-4456 shock machine. The total weight of the table, fixture and unit, the height of the drop and the block arrangement were computed to obtain the required 15 G shock for a duration of 11 ± 1 milliseconds. The unit then was subjected to 3 shocks of the required magnitude and duration in the plus and minus directions of each axis. The test was repeated with the unit mounted so the shocks were applied in each of the three mutually perpendicular axes for a total of 18 shocks.

5.12.3 Results -- At the conclusion of the test, the unit was examined visually for damage. There was no visible damage. The unit was considered to have passed the Shock Test as conducted in this Laboratory and was returned to the manufacturer for evaluation and functional check-out.

TEST EQUIPMENT LIST

Items maintained within current calibration period.

-Absolute Manometer: Meriam Model 31EC10, S/N L61781, 35". Mercurial manometer reading from sea level to 150,000 ft. altitude. Used to measure PSIA during High Temperature and Oxygen Atmosphere Tests.

-Altitude Chamber: Veeco Model VE-401A, S/N 5011. Ultimate vacuum 1×10^{-8} torr. Equipped with calibrated thermocouple vacuum gages for monitoring evacuation of system. Used for the Decompression Test.

-Accelerometer: Endevco Model 2242M4, S/N AA14, 6.80 rms mv/peak g. Used to monitor and control vibration level during the Vibration Test.

-Centrifuge: Wright Engineering Model 20. Sustained acceleration to 100 g's. Unit equipped with calibrated tachometer for accurate determination of acceleration applied to the specimen during the Acceleration Test.

-Humidity Chamber: Equatorial Model 3, S/N CE-132. Equipped with controls adjusted to provide compliance with MIL-E-5272C, Para. 4.4.1, Proc.I. Chamber used for conducting Humidity Test.

-Explosion Chamber: Wright Engineering Model 1. Unit equipped with calibrated altimeter and vacuum pump for evacuation to required altitudes. Chamber equipped with ignition and sampling devices for verification of the explosiveness of the atmosphere. Used to conduct the Explosive Atmosphere Test.

-Salt Spray Chamber: Wright Engineering Model 18, S/N CE-6. Complete with bubble tower. Chamber temperature 95°F. Chamber used to conduct the Salt Spray Test.

-Sand and Dust Chamber: Tech-Quip Model 515. Equipped with temperature control to maintain prescribed levels. Chamber used to conduct the Sand and Dust Test.

-Shock Machine: MIL-S-4456 Model 20VI sand drop machine. Equipped with proper arresting blocks for 11 ± 1 millisecond half sine pulses. Used with calibration chart for the required shock intensity.

-Temperature Progress-Controller: West Model JPG, S/N 5709460. Range 0 to +300°F. Thermocouple controlled.

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TEST EQUIPMENT LIST (Cont'd)

Items maintained within current calibration period.

-Thermocouple Bridge: Wheelco Model 311, S/N 206. Range -100 to +1000°F.

-Temperature Chamber: Missimers Model FTA 12-85 x 200 Temperature range -80 to +200°F. Used to conduct the Low Temperature Test.

-Vibration Exciter: Unholtz-Dickie Model 91M System. Shaker Model 500, S/N 112, rated at 4000 force pounds with random excitation. Model A105 power amplifier, S/N 509. System equipped with following major items of support equipment:

--Sinusoidal Oscollator & Controller: MB Model N575/N576, S/N 121760 (B & K Model 1028)

--Voltage Level Recorder: B & K Model 2305, S/N 83140. For X-Y plot of equalization.

--Dynamic Analyzer: Spectral Dynamics Model SD101A, S/N 121, with Model SD-11 Constant Output Level Adapter, S/N 155, with 20 and 5 CPS tracking filters.

--Spectrum Equalizer: MB Model N300, Type 6, S/N 468. Part of Model T285. 80 Channel Mixed Filter Random Console, ME 80/12.5/25/50, S/N 352.

GARWOOD LABORATORIES, INC.

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TEST REPORT

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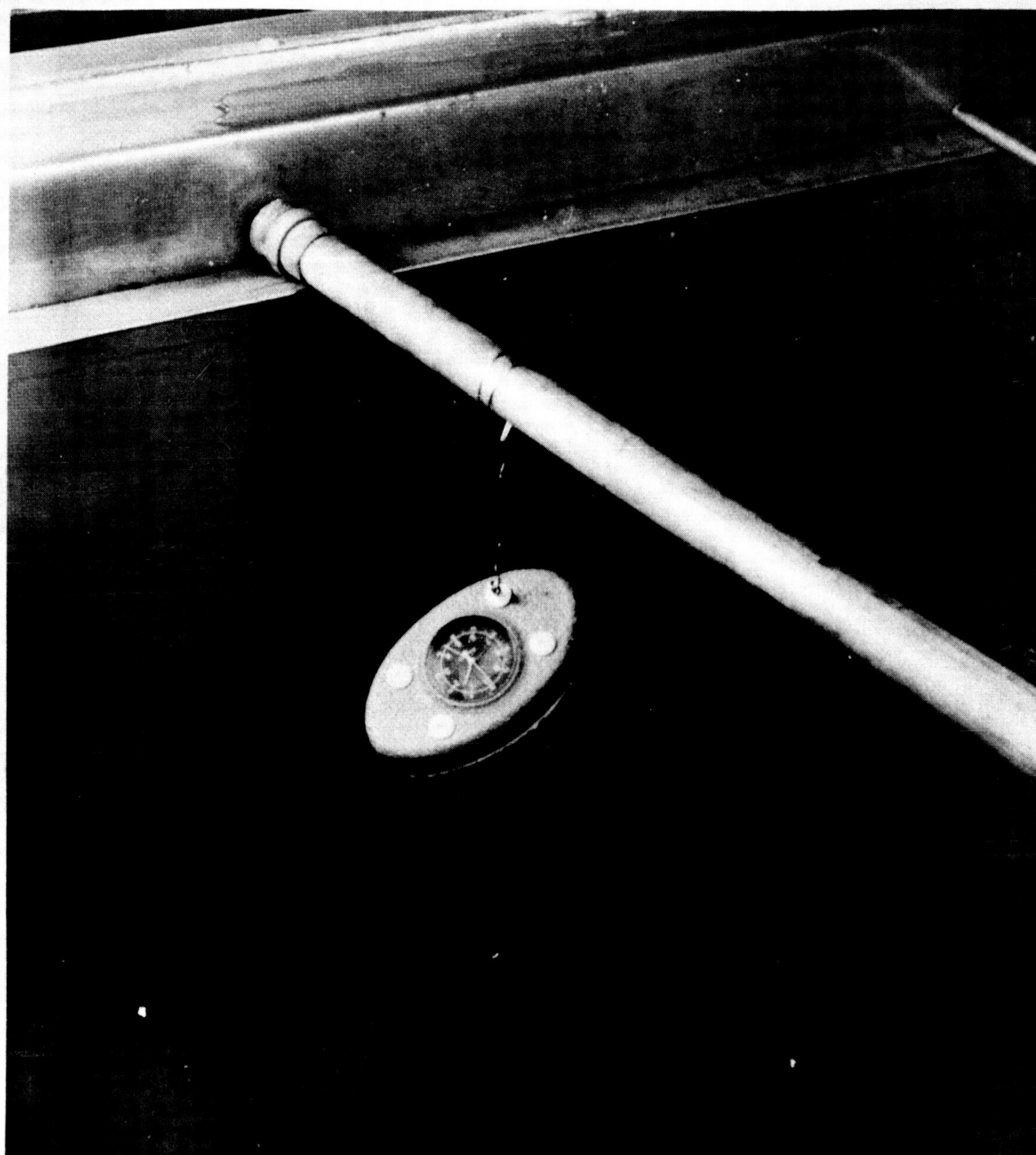
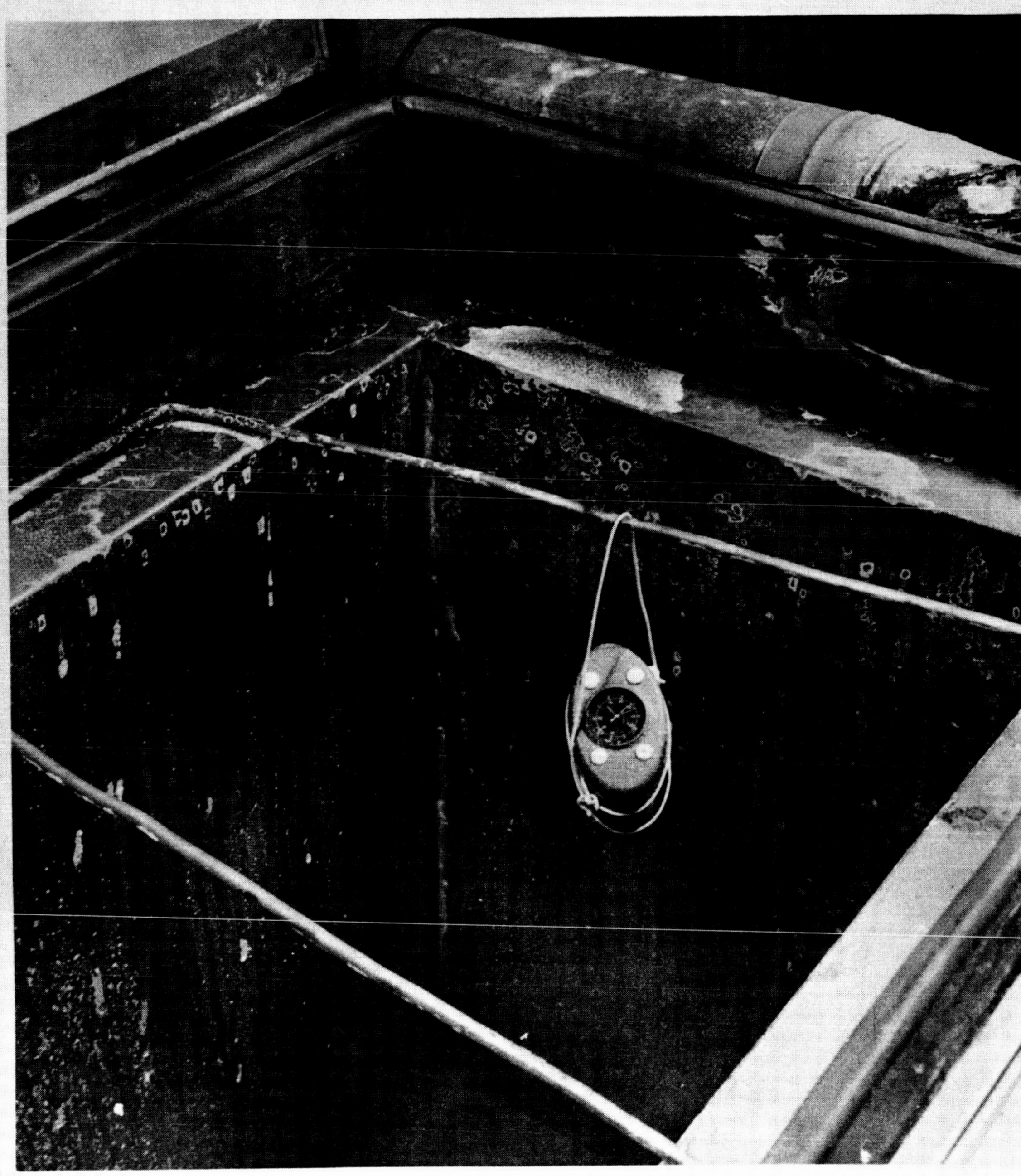
PHOTO 1

AFTER HUMIDITY TEST



AFTER SALT SPRAY TEST



G 10 9 PHOTO 2 C 11-8

GARWOOD LABORATORIES, INC.
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MONTEBELLO, CALIF.
TEST REPORT

REPORT NO. 3161
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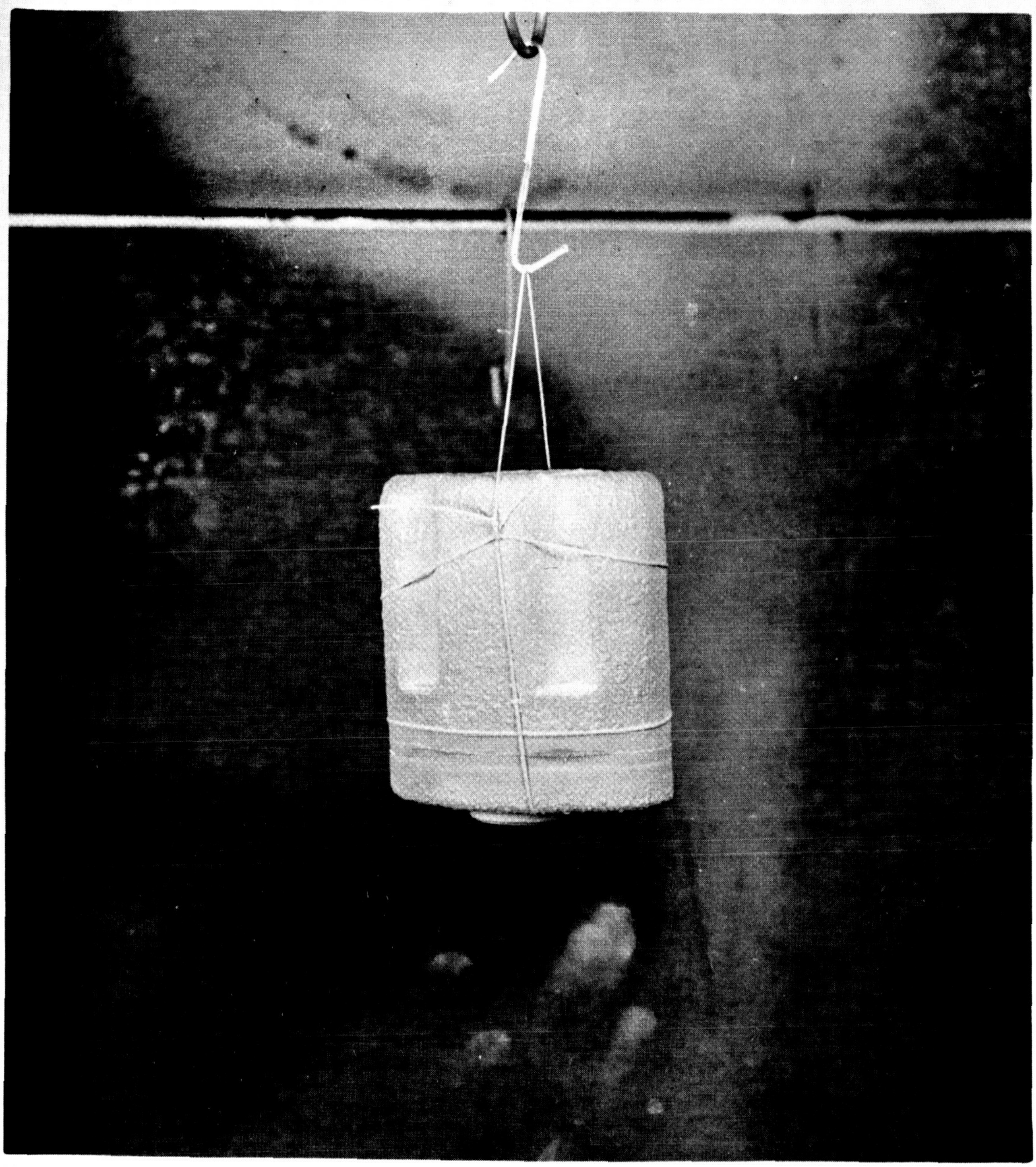
PHOTO 3

AFTER SAND AND DUST TEST



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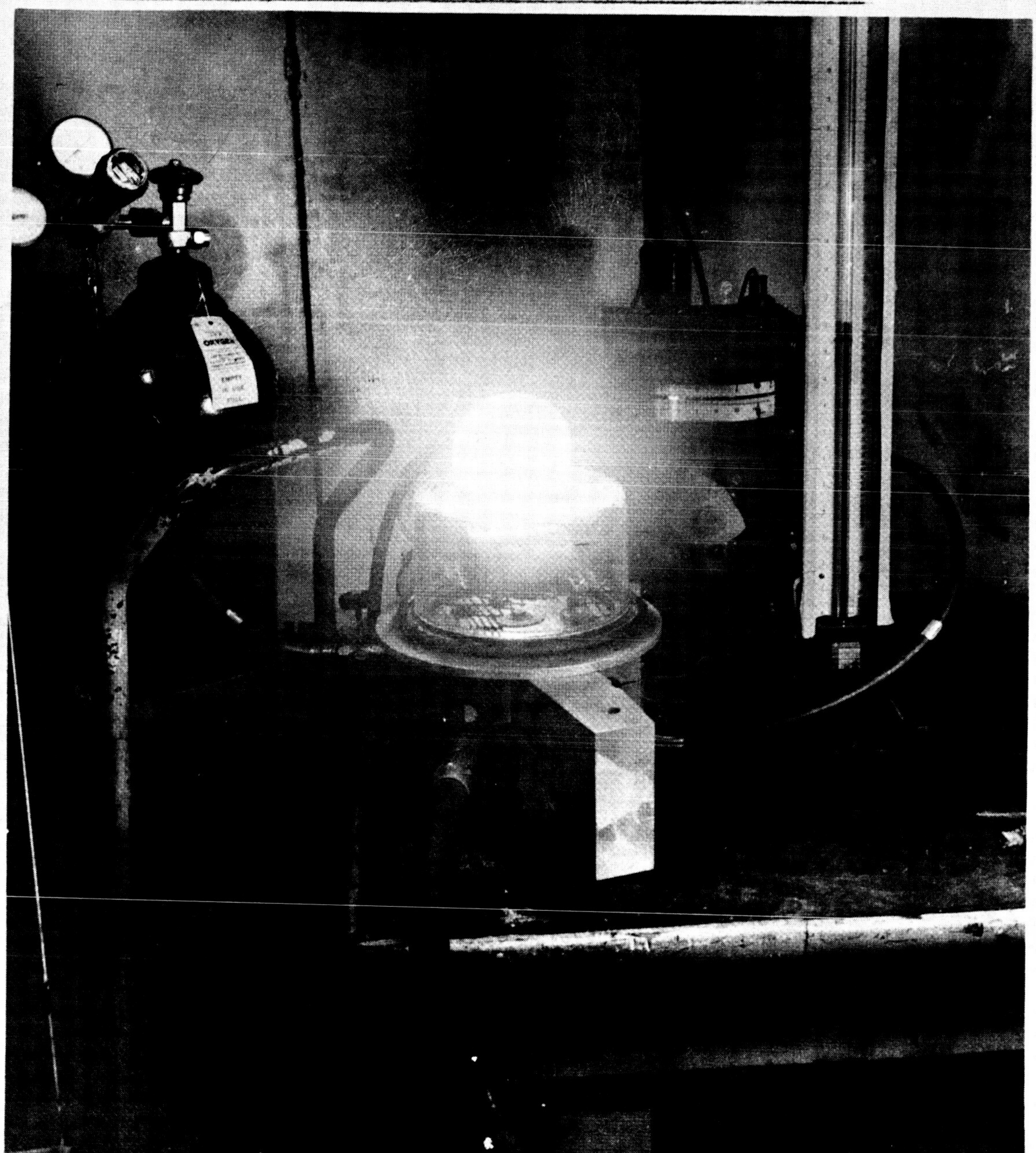
MONTEBELLO, CALIF.
TEST REPORT

REPORT NO. 3161
PAGE 21
PHOTO 4

HIGH TEMPERATURE - OXYGEN ATMOSPHERE TEST SETUP



GARWOOD LABORATORIES, INC.

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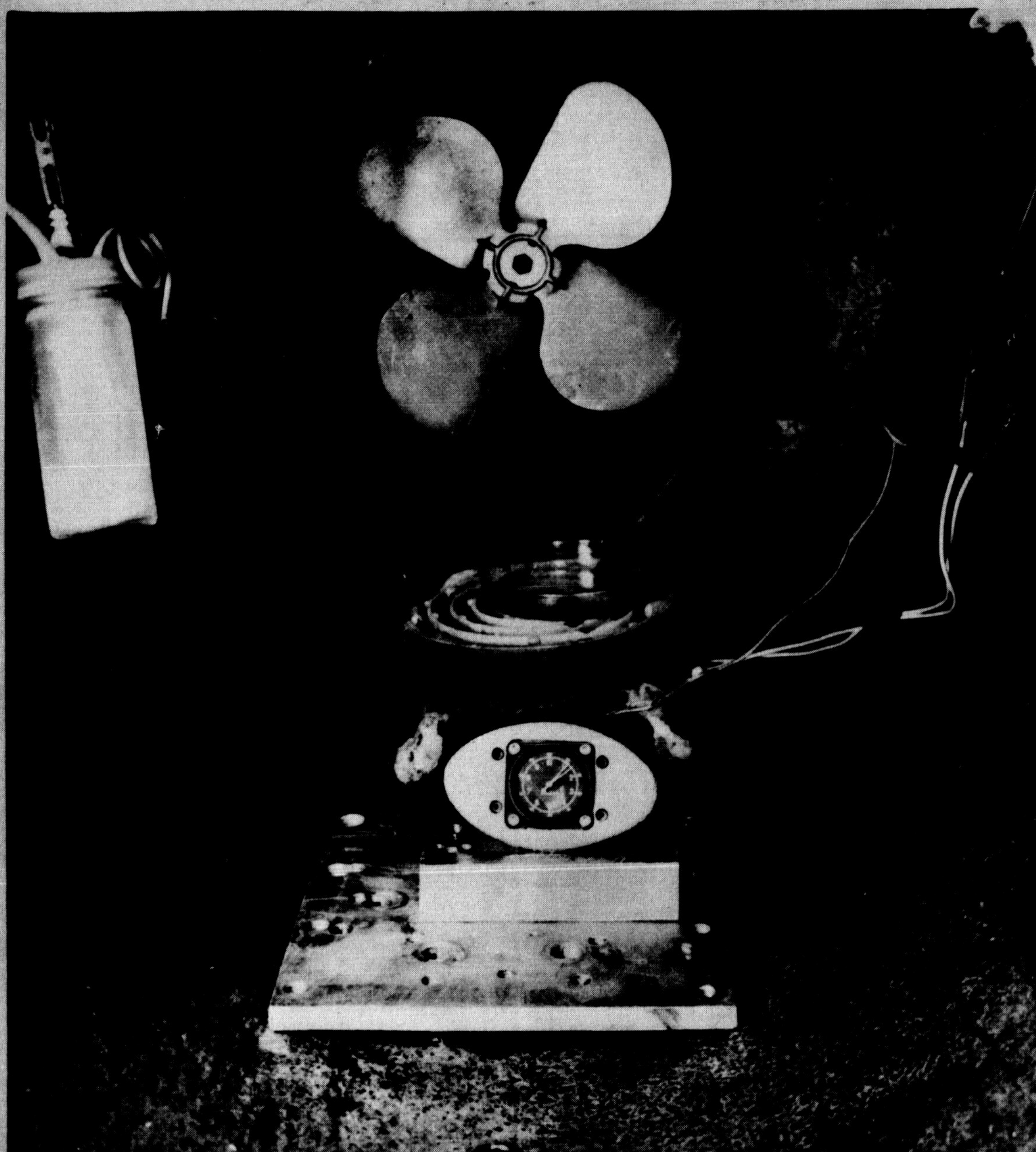
MONTEBELLO, CALIF.
TEST REPORT

REPORT NO. 3161
PAGE 22
PHOTO 5

EXPLOSION TEST SETUP



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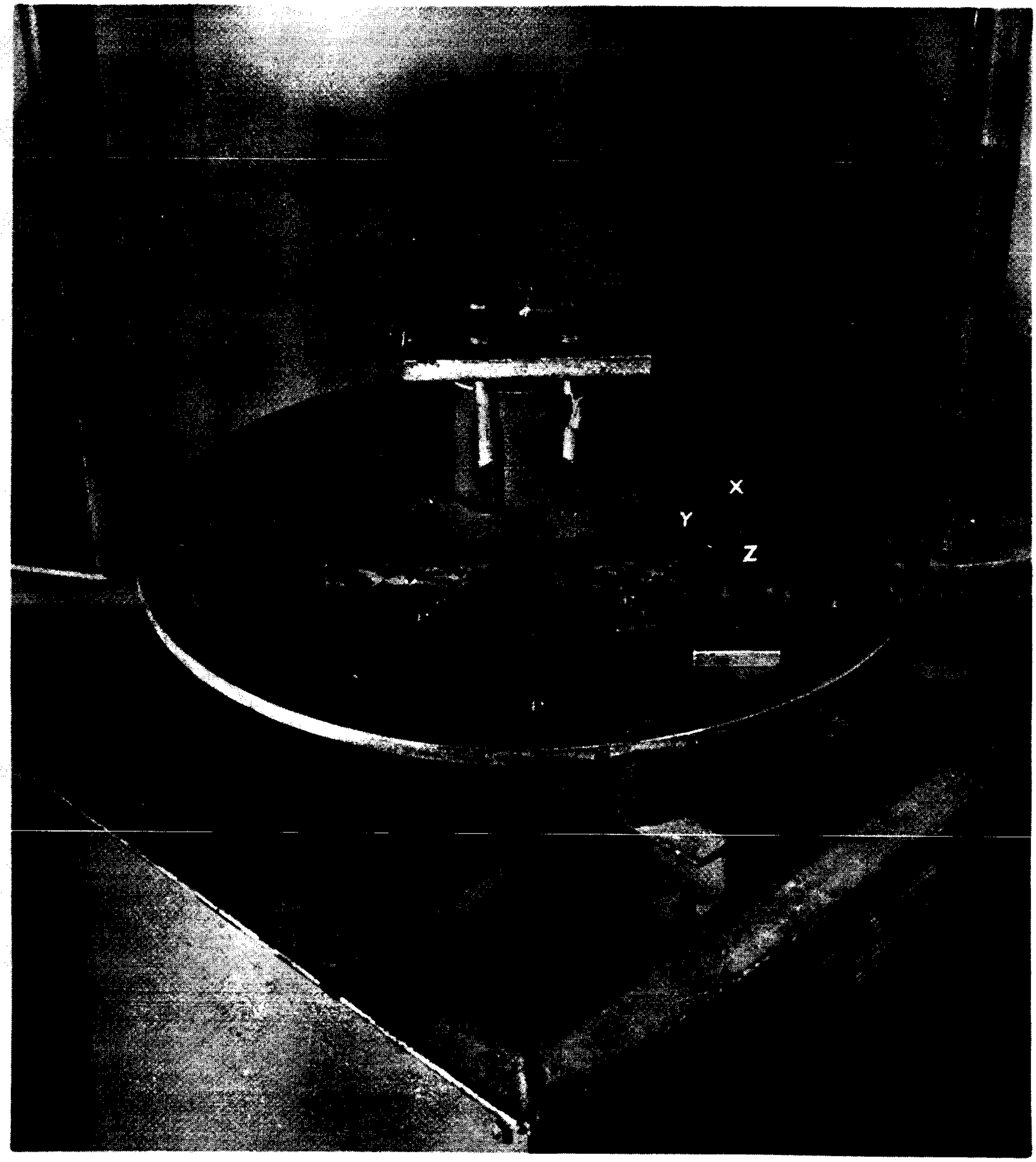
G 10 S PHOTO 2 C 11-8

SHOCK TEST SETUP



GARWOOD LABORATORIES, INC.

Report No. 3161
Page 24
Appendix I
TEST REPORT 6005

ROTOTEST laboratories, inc.

2803 LOS FLORES BLVD. / LYNWOOD, CALIFORNIA /

Service To:	APPLICABLE TEST SPEC.
GARWOOD LABORATORIES, INC. 708 SOUTH VAIL AVENUE MONTEBELLO, CALIFORNIA	PER VERBAL INSTRUCTIONS OF MR. C. MEYERS OF GARWOOD LABORATORIES.
	NAME & P.N. OF SAMPLE: ION CHAMBER DOSIMETER SYSTEM
	SAMPLE S.N.: RTL No. 1
Purchase Order No. 2161-CFM	GOV'T CONT. NO. N/A — AMBIENT TEMP. 25 °C

PROCEDURE:

ACOUSTIC NOISE

THE TEST SPECIMEN WAS PLACED WITHIN THE ROTOTEST LABORATORIES ACOUSTIC FACILITY AND SUBJECTED TO THE PRESCRIBED ACOUSTIC NOISE EXPOSURE.

THE OVERALL SOUND PRESSURE LEVEL WAS 135 DB COVERING THE FREQUENCY SPECTRUM OF 20 CPS TO 10KC. THE OCTAVE BAND SOUND PRESSURE LEVELS WERE AS INDICATED ON PAGE 2, HEREIN.

THE TEST SPECIMEN WAS SUBJECTED TO THE NOISE EXPOSURE FOR 30 MINUTES; 10 MINUTES IN EACH OF THREE MUTUALLY PERPENDICULAR AXES.

UPON COMPLETION OF THE NOISE EXPOSURE THE TEST SPECIMEN WAS VISUALLY EXAMINED FOR EVIDENCE OF PHYSICAL DAMAGE AND RETURNED TO GARWOOD LABORATORIES.

EQUIPMENT:

NAME	MFR.	MODEL	S.N.	CALIB. LAST	CALIB. DUE
OCTAVE BAND NOISE ANALYZER	GENERAL RADIO	1550A	611	1/5/65	7/5/65
SOUND LEVEL METER	GENERAL RADIO	1551A	2087	4/26/65	10/26/65
SOUND LEVEL CALIBRATOR	GENERAL RADIO	1552B	E-3303	12/1/64	12/1/65
RANDOM NOISE GENERATOR	GENERAL RADIO	1390B	3251	1/11/65	7/11/65
ALTEC-LANSING MICROPHONE	ALTEC-LANSING	21-BR-180-1	--	BEFORE USE	
STOP WATCH	MINERVA	--	753	11/9/64	5/9/65

RESULTS: SEE PAGE 2.

Tests Conducted By:
JAMES HOLDER Date 4/29/65

Certified By: [signature]
QUALITY CONTROL ENGINEER

COUNTY OF LOS ANGELES } SS
STATE OF CALIFORNIA }

[signature]
being duly sworn, deposes and says: That the information contained in this report is the result of complete and carefully conducted tests and is to the best of his knowledge true and correct in all respect.
SUBSCRIBED and sworn to before me this 4TH day of MAY, 19 65

[signature]
Notary Public in and for the County of Los Angeles, State of California
My commission expires 3/26, 19 68

LR

ROTOTEST laboratories, inc.

2603 LOS FLORES BLVD. / LYNWOOD, CALIFORNIA /

ACOUSTIC NOISE - CONTINUED

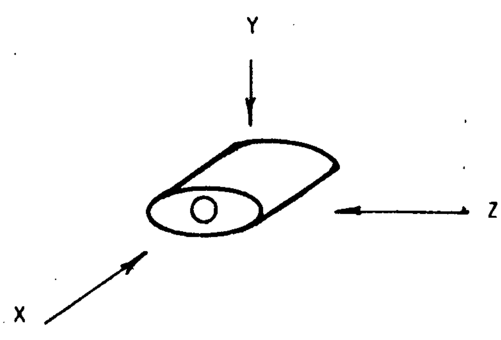
RESULTS:

FREQUENCY BANDS (CPS)	OCTAVE BAND LEVELS (DB)	OVERALL SOUND PRESSURE LEVEL (DB)
20 - 75	120	135
75 - 150	123	
150 - 300	127	
300 - 600	130	
600 - 1200	128.5	
1200 - 2400	125	
2400 - 4800	121.5	

VISUAL EXAMINATION:

THE SPECIMEN DISPLAYED NO VISIBLE EVIDENCE OF PHYSICAL DAMAGE RESULTING FROM THE NOISE EXPOSURE.

DEFINITION OF AXES:



APPENDIX 2

REPORT OF INTERFERENCE TEST
ON
ION CHAMBER DOCIMETER SYSTEM

Prepared for
GARWOOD LABORATOR ES, INC

FILTRON COMPANY, INC.
CULVER CITY, CALIFORNIA
SYSTEMS ENGINEERING DIVISION

REPORT NO. FL-4116-T-1-65

18 May 1965

APPENDIX 2

FILTRON COMPANY, INC.

FL-4116-T-1-65

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or any data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

ADMINISTRATIVE DATA

PURPOSE OF TEST:

The purpose of this test was to determine compliance of the Ion Chamber Docimeter to the Class I requirements of MIL-I-26600.

MANUFACTURER:

General Dynamics - Fort Worth

MANUFACTURER'S MODEL NUMBER:

None available

QUANTITY OF ITEMS TESTED:

One

SECURITY CLASSIFICATION OF ITEM:

Unclassified

DATE TEST COMPLETED:

5 May 1965

TEST CONDUCTED BY:

Filtron Company, Inc.

TEST CONDUCTED FOR:

Garwood Laboratories, Inc.

DISPOSITION OF SPECIMEN:

Returned to Garwood Laboratories, Inc.

ABSTRACT:

Radiated interference and susceptibility tests were performed on the test unit to determine compliance with MIL-I-26600. The unit was found to comply with the specification requirements.

FACTUAL DATA

1.0 DESCRIPTION OF TEST UNIT

The test unit was a portable battery powered ion chamber docimeter system

The test unit was encased in an insulated housing and completely portable with no provisions for external power.

2.0 DESCRIPTION OF TEST APPARATUS

A complete list of the test equipment utilized during these tests is listed in Appendix I.

3.0 TEST PROCEDURE

3.1 General:

When making measurements of radiated interference, the entire specified spectrum was scanned to determine the maximum levels of interference. At least three measurements per octave were recorded of these maximums.

Broadband interference measurements were performed using the peak detector function on the noise and field intensity measuring instrument.

Since the test unit was encased in an insulated housing and had no provisions for external power or external grounding, all interference tests were performed with the test unit ungrounded.

In that the test specimen was completely self-contained with battery and without any external power leads, conducted interference measurements are deemed not applicable to this test series.

3.2 Radiated Measurements

Measurements of the radiated interference emanating from the unit were made using the antennas specified below. In all cases the antenna was positioned at a distance of one foot from the unit and adjusted for maximum indicated level on the noise and field intensity meter.

Antenna	Frequency Range
41" Rod	150kc to 25mc
35mc Dipole	25mc to 35mc
Tuned Dipole	35mc to 1gc

3.3 Susceptibility Measurements

3.3.1 General

Monitoring of the test specimen during the susceptibility tests was accomplished by observing the only included provision for such monitoring: the radiation indicator scale.

As in the case of conducted interference, the test specimen was completely self-contained without any power leads, and therefore, conducted susceptibility tests are not applicable to this test series.

3.3.2 RF Radiated Susceptibility

Radiated susceptibility measurements were performed by subjecting the unit to fields established with the following antennas over the specified range of frequencies.

Antenna	Applied Voltage	Frequency Range
41" Rod	0.1 Volts	150kc to 25mc
35mc Dipole	0.1 Volts	25mc to 35mc
Tuned Dipole	0.1 Volts	35mc to 1,000mc
Non Directive	0.1 Volts	1mc to 10gc

4.0 TEST RESULTS

4.1 Radiated Interference

No broadband interference was encountered in the range of 150kc through 400mc as shown graphically on Page one of Appendix II.

4.2 RF Radiated Susceptibility

When subjected to the radiated fields as specified in the test procedure no degradation of performance was noted across the frequency range of 150kc to 10gc.

5.0 CONCLUSIONS

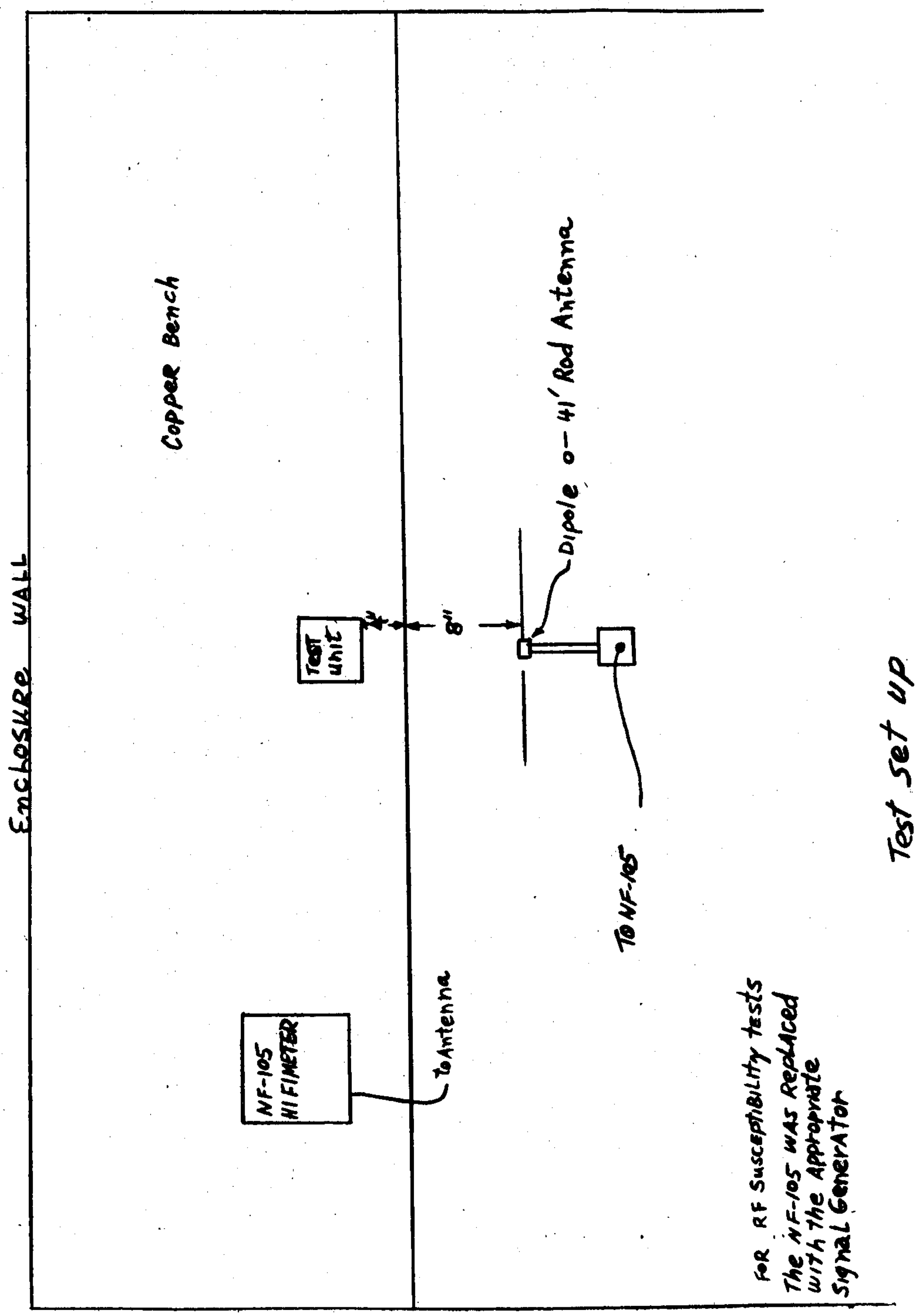
The unit complied with the requirements of the specification.

Prepared by: L. D. Cochneuer

Approved by: A. J. Devot
Chief Engineer
Systems Engineering Division

APPENDIX I

TEST EQUIPMENT AND CONFIGURATION



Enclosure WALL
Copper Bench
Test unit
8"
Dipole 0-41' Rod Antenna
To NF-105
Test Set up
NF-105 HI FIMETER
To Antenna
FOR RF Susceptibility tests The NF-105 WAS Replaced with the Appropriate Signal Generator

1.0	INTERFERENCE TEST FACILITIES AND EQUIPMENT

1.1 Shielded Enclosure, Filtron double shielded cell type of screened construction 10' by 24'.

1.2 Noise and Field Intensity Meter, Empire Devices Model NF-105 Serial No. 128 and following accessories.
Last Calibration Date: April 28, 1965

1.2.1 Tuning Units

TA/NF-105,	.150mc - 25mc
TI/NF-105,	25mc - 200mc
T2/NF-105	200mc - 400mc

1.2.2 Antennas

VA-105 41" Rod	.150mc - 25mc
DM-105-T1 Dipole	20mc - 200mc
DM-105-T2 Dipole	200mc - 400mc

1.3 Noise and Field Intensity Meter, Polarad Model FIM and following accessories, Serial No. 146
Last Calibration Date: March 12, 1965

1.3.1 Tuning Units

FIM-L Tuning Unit	1.00 - 2.24gc
FIM-S Tuning Unit	2.14 - 4.34gc
FIM-M Tuning Unit	4.20 - 7.74gc
FIM-X Tuning Unit	7.36 - 10.00gc

1.3.2 Antennas

CA-B Broadband	1.0 - 10.0gc

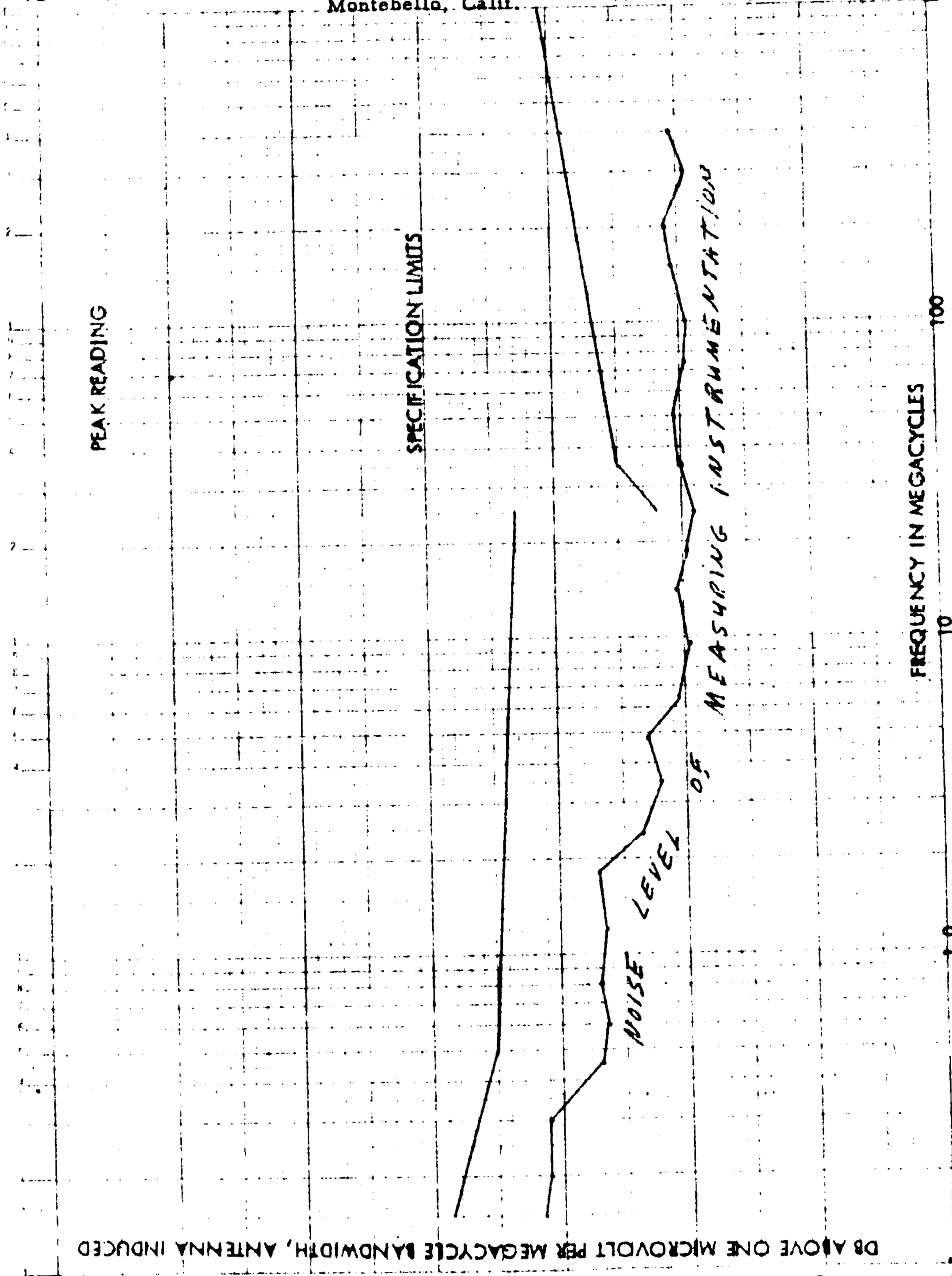
1.4 Signal Generator, Hewlett-Packard, Model 606, Serial No. 038024.31
Last Calibration Date: March 9, 1965

1.5 Signal Generator, Hewlett-Packard Model 608, Serial No. 2032
Last Calibration Date: March 23, 1965

1.6 Signal Generator, Hewlett-Packard Model 612, Serial No. 29901709
Last Calibration Date: January 6, 1965

APPENDIX II

GRAPHICAL DATA



BROADBAND RADIATED INTERFERENCE

FILTRON COMPANY, INC.

APPENDIX III

TABULAR DATA AND SAMPLE CALCULATIONS

1.0 SAMPLE CALCULATIONS

1.1 Radiated Measurements

Interference Measuring Equipment - NF-105		
Frequency of broadband measurement		14mc
Antenna Factor - Rod Antenna	(A)	+ 11 db
Cable Loss Factor	(B)	0
Meter Reading	(C)	30db - uv/mc
Interference Level = A + B + C =		41db - uv/mc

Interference Measuring Equipment - NF-105		
Frequency of broadband measurement		35mc
Antenna Factor - Dipole	(A)	7.7db
Cable Loss Factor	(B)	0.3db
Meter Reading	(C)	32db - uv/mc
Interference Level = A + B + C =		40db - uv/mc

ENGINEERING DEPARTMENT

FILTRON COMPANY, INC.

ENGINEERING TEST REPORT

RADIO FREQUENCY SUPPRESSION LABORATORY

PROJECT RFI TEST FOR GARWOOD LABORATORIES INC PAGE NO. 2
ON ONE ION CHAMBER DOSIMETER SYSTEM DATE 5-5-65
TO MIL-I-26600 CLASS 1

BROADBAND RADIATED INTERFERENCE

FREQ MC	METER READING db-uv/MC	ANTENNA CORRECTION FACTOR db	CORRECTED METER READING db-uv/MC	MIL-I-26600 LIMIT db-uv/MC	FREQ MC
.15	33	30	63	77	
.20	33	29	62	75.4	
.30	32	30	62	73	
.45	30	24	54	70.6	
.60	28	25	53	69.8	
.80	27	27	54	69.5	
1.2	31	22	53	69.2	
1.8	30	24	54	68.7	
2.4	29	18	47	68.5	
3.[illegible]	28	16	44	68	
4.8	27	19	46	67.7	
6.5	28	13	41	67.5	
9.6	27	12	39	67	
14	30	11	41	66.6	
19	30	9.5	39.5	66.4	
25	30	8	38	66	
25	30	8	38	44	
35	32	8	40	50	
50	32	9	41	51.2	
75	30	9	39	52.4	
100	30	9	39	53.2	
150	32	9	41	54.5	
200	32	10	42	55.5	
300	29	10	39	56.6	
400	31	10	41	57.6	

COMMENTS THE ABOVE "METER READINGS" ARE NOISE LEVEL READINGS OF THE MEASURING INSTRUMENT

THE ABOVE "CORRECTED METER READINGS" ARE NOISE LEVEL READINGS OF THE MEASURING INSTRUMENTATION

NO INTERFERENCE WAS DETECTED ABOVE THE INSTRUMENTATION SENSITIVITY OVER THE FREQUENCY RANGE OF .15 TO 400 MC

SIGNED	DATE	ENGINEER	DATE	DEPT ENG R	DATE	CHIEF ENGR	DATE
		[illegible signature]	5-5-65				

FR-1200 FORM FO-15

APPENDIX C

EVALUATION OF ION-CHAMBER READOUT HEADER

APPENDIX C

EVALUATION OF ION-CHAMBER READOUT HEADER

A quartz-fiber electrometer assembly was evaluated to determine its applicability in the design of a small, lightweight integrating dosimeter system. For the evaluation, two Model 1000-1 quartz-fiber electrometer assemblies, based on a design by Neher (Refs. 3 and 4) for his automatic-recharging ionization chamber, were purchased from Electro-Optical Systems, Inc. In this design a quartz fiber is placed in tension against a quartz rod. When voltage is applied to the fiber, the assembly is charged and the fiber is repelled from the post. The post may be discharged by ionization in the surrounding gas, or by contact to ground through a resistor. As the charge on the post is reduced the tension in the fiber returns it to the post and the cycle is repeated. The amount of charge transferred per cycle is proportional to the voltage charge on the post and its capacitance to ground. The units obtained from EOS recycled with a charge of ~ 25 v on the center post. The fiber faces are made to conduct by means of an aquadag coating, while in Neher's original units the post was aquadaged and the fiber was coated with gold.

In the units received from EOS, a copper shield is placed around the fiber mounting. A major part of the evaluation was to determine the necessity of this shield, since it cannot be tolerated in a small ion chamber. The original purpose of the shield, described by Neher in Reference 2, was to make the pull-in voltage of the fiber independent of the supply voltage. In this test, the shield and fiber voltage were varied independently while the average current from the post and the time interval between fiber contacts were measured. Measurements were also made with the hi-meg resistor removed and a Co^{60} source near. A schematic of the testing arrangement is shown in Figure C-1.

The measured effects of fiber and shield voltages on sensitivity are shown in Figure C-2. As the shield voltage is lowered the sensitivity decreases, or the charge-transfer per pulse increases. An equivalent change is observed when the shield is grounded and the fiber voltage is raised. The sensitivity variation between individual pulses was erratic. Long periods of stable operation alternated with long periods of erratic operation. Multiple pulses or "bounce" was observed from the fiber output during erratic operation. The unit was operated open to the air, and operation might have been more

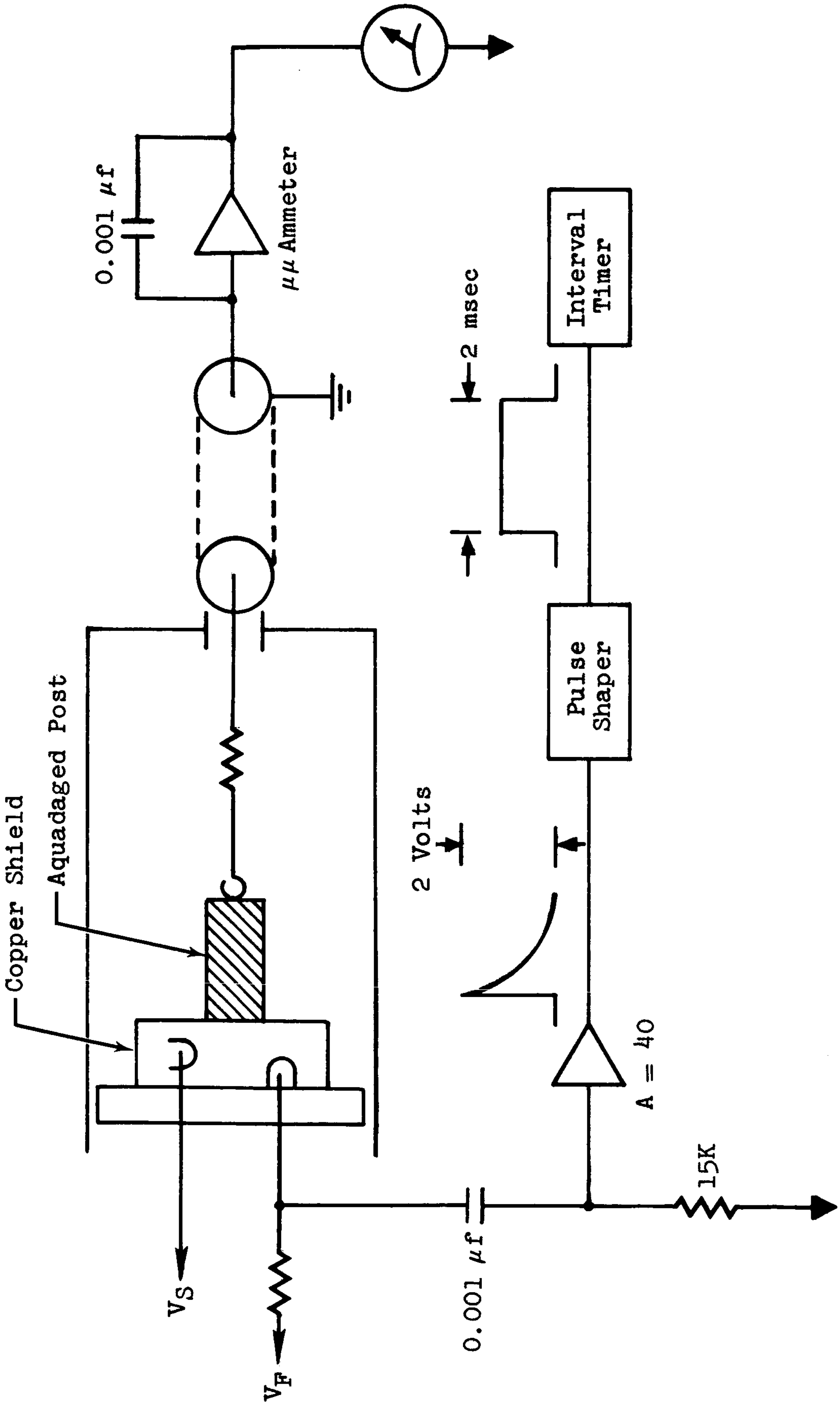


Figure C-1 Schematic of Test Arrangement

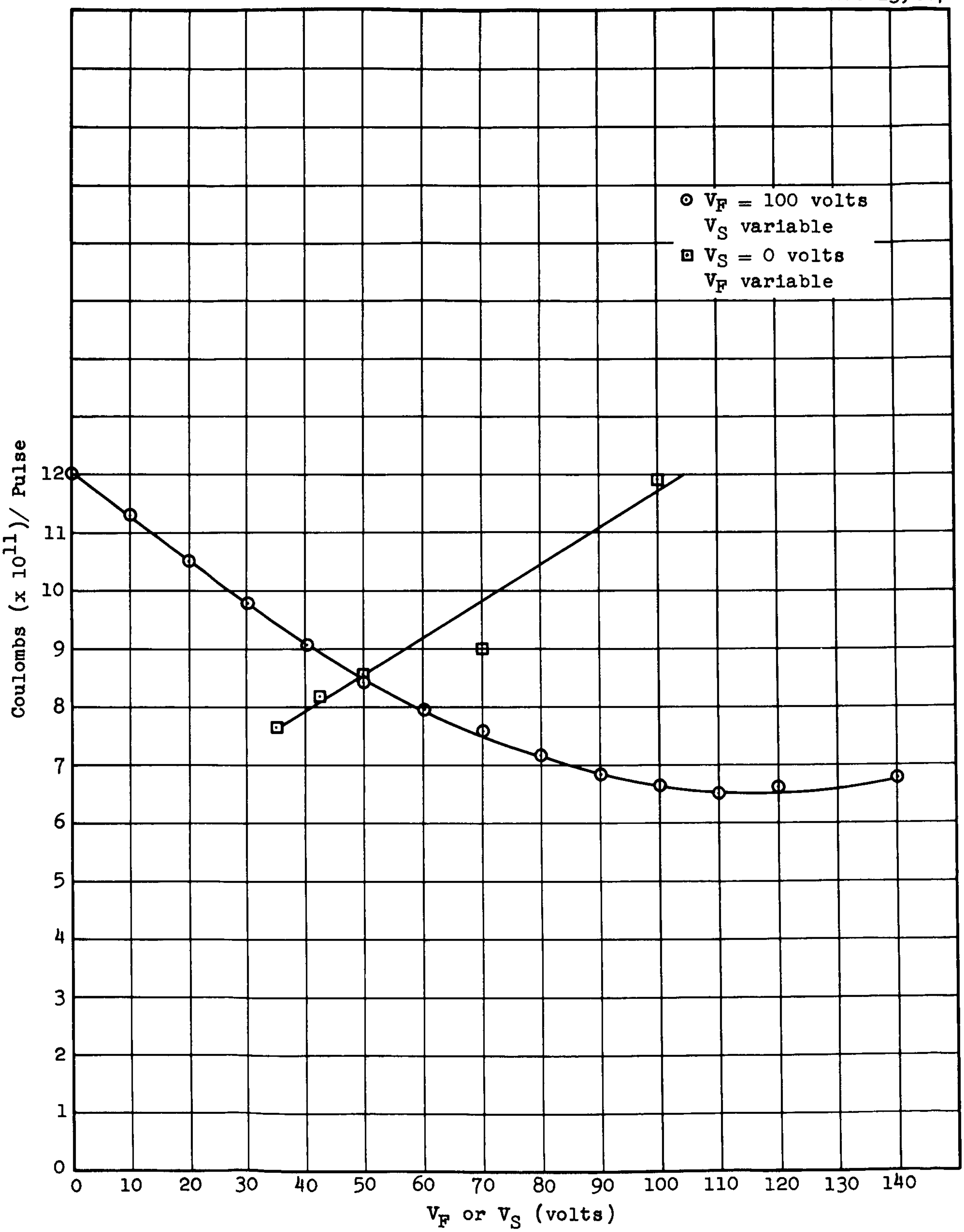


Figure C-2 Fiber Sensitivity as a Function of Shield and Filament Voltage consistent if it had been sealed in a container and baked out. On several occasions the fiber stuck to the center post and had to be shaken free.

The ion current from a gamma source was measured with the shield grounded and with the shield at the fiber voltage. It was found that the current with the shield grounded was about twice as great as with the shield at fiber voltage. This result was expected, since, with the shield at the fiber voltage, the ion current in the volume enclosed by the shield opposes the ion current to the center post of the volume external to the shield. Also, the low field inside the shield gives poor saturation characteristics at high dose rates. For these reasons a shield cannot be used in a low-volume ion chamber. The only disadvantage in not using an electrostatic shield around the fiber is that the header sensitivity depends on the fiber voltage.

A quartz electrometer of this type would be worth trying in a light-weight, small-size integrating dosimeter. High resistance circuitry would not be required since the only element requiring good insulation is the center post inside the ion chamber. The principle problem in the ion chamber construction would be to build units with similar sensitivities that are stable to temperature and vibration. Stable operation would also be affected by the type of contact made by the quartz fiber. These problems have been solved in the larger units and it should be possible to incorporate the necessary design features in a small ion chamber. Elaborate electronics would not be required. A reasonably stable high-voltage supply, operating in the range of from 50 to 100 v, would constitute the major part of the electronics. The efficiency of this supply would determine the continuous power requirements and, indirectly, the size and weight of the package.

APPENDIX D

LIST OF MECHANICAL AND ELECTRICAL DRAWINGS FOR NAS9-3407 FLIGHT-QUALIFIED WHOLE-BODY DOSIMETER SYSTEM

APPENDIX D

LIST OF MECHANICAL AND ELECTRICAL DRAWINGS FOR NAS9-3407 FLIGHT-QUALIFIED WHOLE-BODY DOSIMETER SYSTEM

The drawings listed here were furnished to MSC-NASA. Originals are on file at NARF, GD/FW.

Dwg. No.	Sheet	Title	Description
NLE-268	1 of 1	Flight-Qualified Dosimeter System (Apollo), Model NDS-23	Schematic
NLM-187	1 of 1	Assembly, Ionization Chamber, Flight-Qualified Dosimeter System (Apollo), Model NDS-23	Assembly
NLM-185	1 of 3	Machined Parts, Ion Chamber, Flight-Qualified Dosimeter System (Apollo), Model NDS-23	Details
	2 of 3	As above	Details
	3 of 3	As above	Details
NLM-186	1 of 1	Assembly, Flight-Qualified Dosimeter System (Apollo), Model NDS-23	

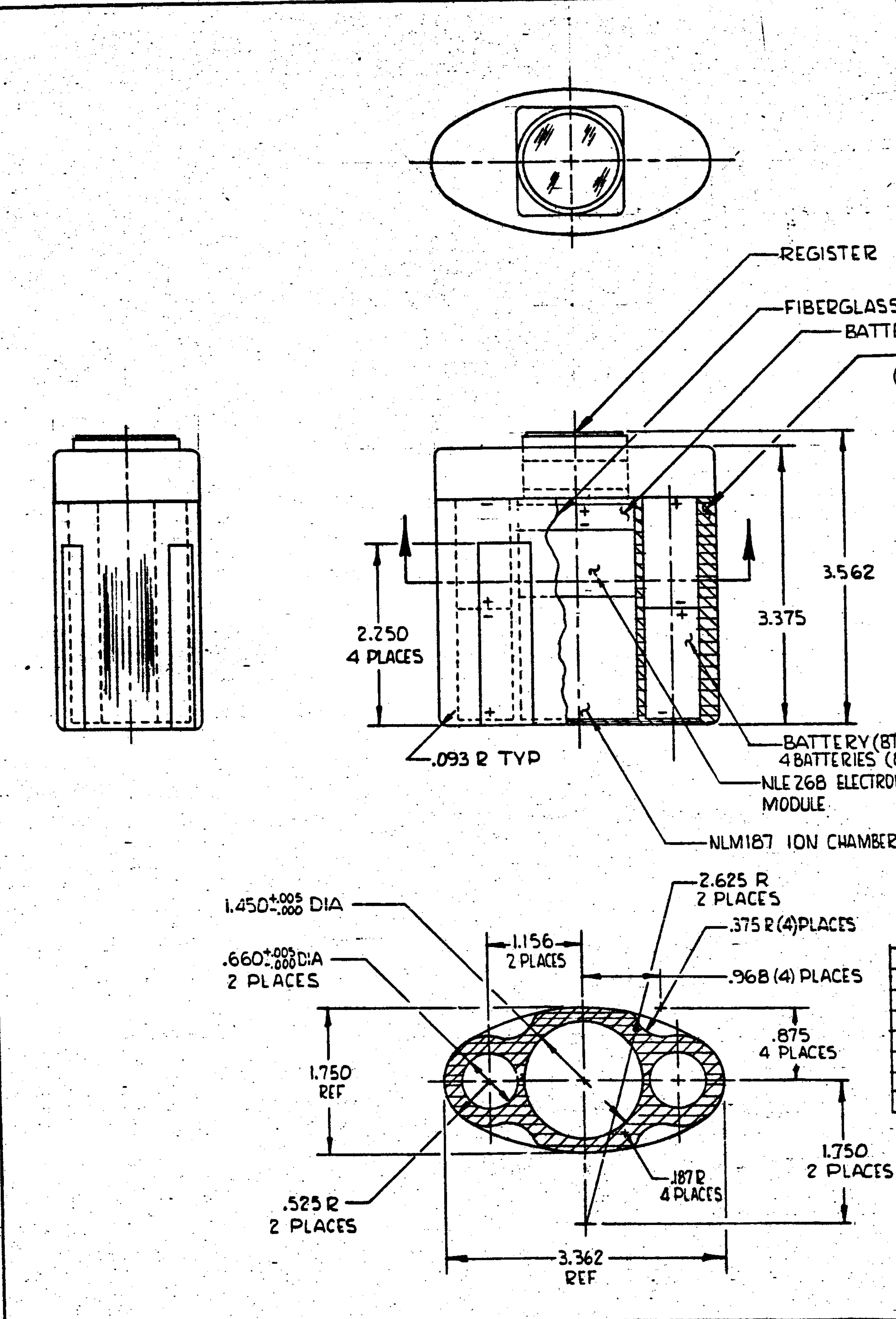
REFERENCES

1. Burton, B. S., Hall, B. C., Development of Personnel Dosimeter Prototypes, Final Report, FZK-174, General Dynamics/ Fort Worth, 31 October 1963.

2. Hine, G. J., Brownell, G. L. (Editors), Radiation Dosimetry, Academic Press, Inc., New York, 1956.

3. Neher, H. V., Rev. Sci. Instr. 24, 99, (1953).

4. Neher, H. V., Johnson, A. R., Rev. Sci. Instr. 27, 173, (1956).



REGISTER
FIBERGLASS
BATTE
3.562
3.375
2.250
4 PLACES
.093 R TYP
BATTERY (BT
4 BATTERIES (
NLE 268 ELECTRO
MODULE
NLM187 ION CHAMBER
1.450 +.005 -.000 DIA
.660 +.005 -.000 DIA
2 PLACES
1.156
2 PLACES
2.625 R
2 PLACES
.375 R (4) PLACES
.968 (4) PLACES
.875
4 PLACES
1.750
REF
1.750
2 PLACES
.187 R
4 PLACES
.525 R
2 PLACES
3.362
REF

SHELL (.020 THK)
RY (BT-1)
POLYSTRENE FOAM
DENSITY 10#/CU.FT.)

)
CELLS)
S

HALF SIZE REPRODUCTION
OF ORIGINAL

BT 2 BATTERY					
BT 1 BATTERY					
REGISTER					
NLE 268 ELECTRONICS MODULE					
NLM187 ION CHAMBER					
DESCRIPTION	STOCK SIZE	MATERIAL	MATL SPECIFICATION	ZONE	CALC UNIT WT

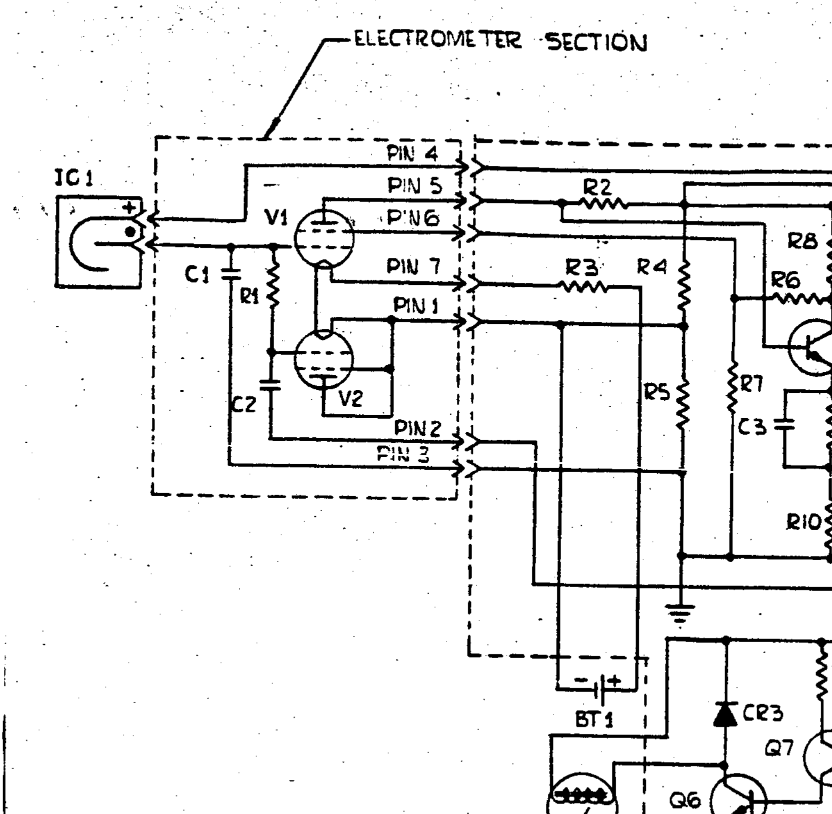
			GOVT
			TECH DSGN
PROJ ENGR			
SR GR ENGR			
GR ENGR			
WEIGHTS			
STRESS			
CHECK			
DESIGN			
DRAFT	R.J. Wilson	3-16-65	SCALE FULL SIZE

ASSEMBLY, FLIGHT - QUALIFIED, DOSIMETER SYSTEM
MODEL NE5-23 (APOLLO)

GD-NUCLEAR
GENERAL DYNAMICS FORT WORTH

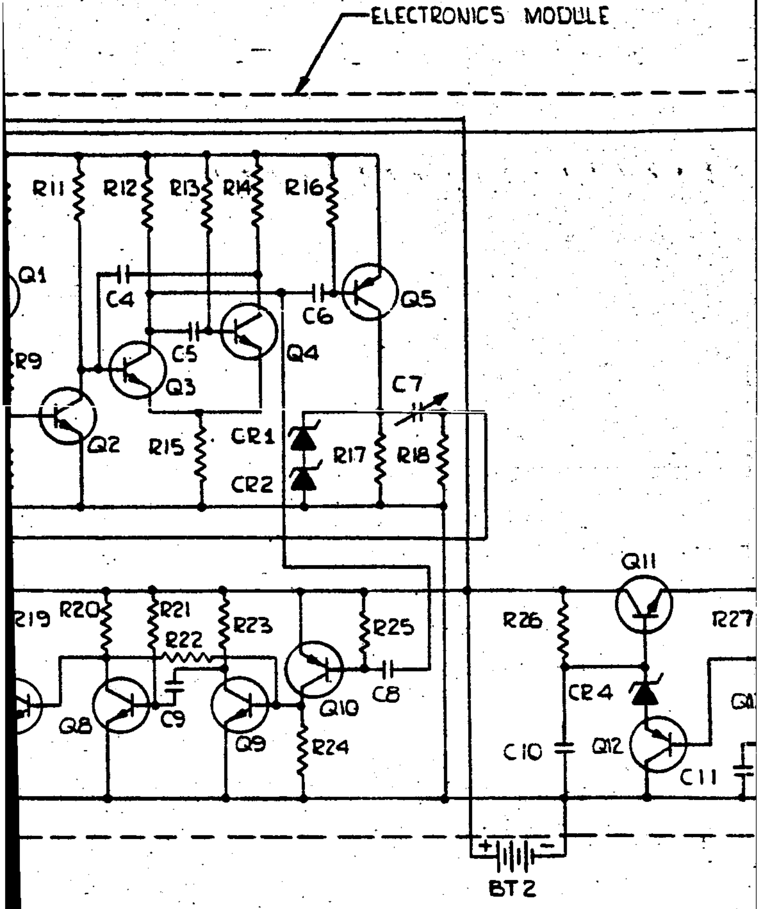
DWG SIZE C | NLM186
CODE E1755 | SH 1 OF 1

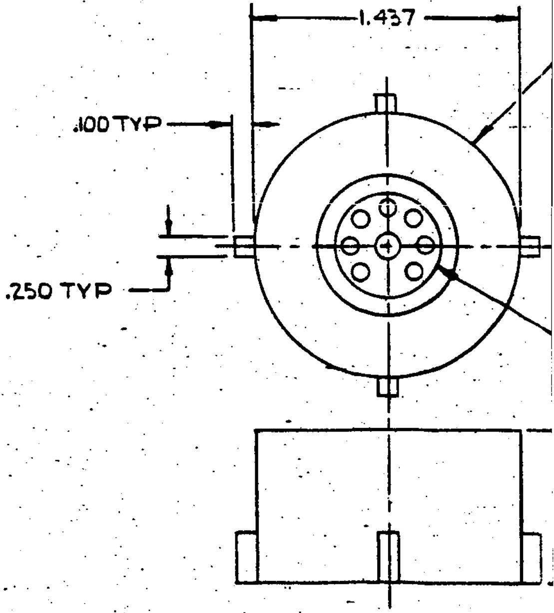
DEPARTMENT 6
FW 1E 9-62 BM & TITLE BLOCK



10. K COML PART: CORNING ELECTRONICS
9. J TEXAS INSTR.
8. H MOTOROLA
7. G FAIRCHILD
6. F BULOVIA WATCH CO
5. E JFD
4. D POTTER & BRUMFIELD
3. C SPRAGUE
2. B CENTRALAB
1. A COML PART: P.R. MALLORY, INC

NOTES





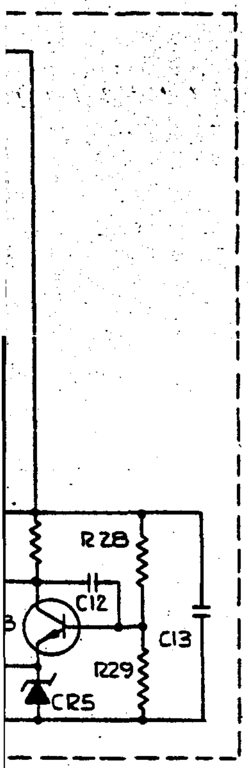
DETAIL OF ELECTRONICS M
AFTER ENCAPSULATION
SCALE: TWICE SIZE

2

NLE 268 SH 1 OF 1

EFF ON

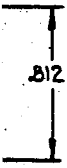
HALF S



PART NO.	OPP DASH NO.	SHN DASH NO.	DESCRIPTION
R28			
R27			
R21			
R18			
R17, R24			
R12, R14, R22, R25			
R11, R13, R23			
R10			
R8, R26, R29, R19			
R7			
R6, R16, R20			
R5, R9, R15			
R4			
R3			
R2			
R1			RESISTOR
CR5			DIODE, ZENER
CR4			DIODE, ZENER
CR3			DIODE
CR1, CR2			DIODE, ZENER
Q7, Q8			TRANSISTOR
Q5, Q10, Q12			TRANSISTOR
Q1, Q2, Q3, Q4, Q9	Q6	Q13	TRANSISTOR
M1			REGISTER
IC 1			ION CHAMBER
C13			CAPACITOR
C12			
C11			
C10			
C9			
C8			
C7			
C6			
C4, C5			
C3			
C1, C2			CAPACITOR
BT 2			BATTERY,4 REQD
BT 1			BATTERY

ENCAPSULATE COMPONENTS WITH STAYCAST #1091 SI 100 PARTS BY WEIGHT TO 23 PARTS BY WEIGHT OF CATALYST # 24 LV (EMERSON & CUMING INC)

CONNECTOR (REF)



ODULE

UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES

LINEAR TOL	.XX	.03
	.XXX	.010
ANGULAR TOL		0°30'

ALL MACHINED SURFACES REF MIL-STD-10

GEN FINISH

HEAT TREAT

PROJ ENGR

SR GR ENGR

GR ENGR

WEIGHTS

STRESS

CHECK

DESIGN

DRAFT

3

REVISIONS

INC	SYM	DESCRIPTION	ZONE	DATE	APPROVED

IZE REPRODUCTION
OF ORIGINAL

56.2K 1/8W 1%	GLASS	RN55D	K	
68K 1/4W 5%	GLASS	RL07	K	
2.7MEG 1/4W 5%		RC07GF 275J		
1000MEGΩ	RESISTIVE PAINT			
221K 1/4W 1%	GLASS	RN65GB 2213F	J	
100K 1/4W 5%	GLASS	RL07	K	
650K 1/4W 1%	GLASS	RN65GB6503F	J	
15K 1/4W 5%	GLASS	RL07	K	
46.4K 1/8W 1%	GLASS	RN55DB4643	J	
1.5M 1/4W 5%		RC07GF155J		
475K 1/4W 1%	GLASS	RN65GB4753F	J	
182K 1/4W 1%	GLASS	RN65GB1823F	J	
562K 1/4W 1%	GLASS	RN65GB5623F	J	
27Ω, 1/4W, 5%		RC07GF 270J		
2.7M, 1/4W, 5%		RC07GF 275J		
22M, 1/4W, 5%		RC07GF 226J		
1N4099			H	
1N725			H	
1N3136			H	
FCT1025			G	
2N718A			G	
2N3136			H	
2N2484			G	
1250Ω, SOLENOID			F	
6.8CC				
4.7MF 50V TANTAL	UM TYPE 150D			
3.3 MF 50V			C	
.22MF 35V			C	
4.7MF 50V TANTAL	UM TYPE 150D		C	
.033MF 100V, 2002	SERIES		D	
51PF 200V 2002	SERIES		D	
1-14MMF VARIABLE	TYPE MC601Y		E	
.01MF, 200V, 2002	SERIES		D	
22 MF, 50V, TANTA	LUM TYPE 150D		C	
56MF, 50V, TANTA	LUM TYPE 150D		C	
22PF, 500V, TYPE	CPR POLYSTYRENE		B	
TRIMR BATTERIES	MADE FROM 16, RM	625R CELLS	A	
RM1438R			A	
STOCK SIZE	MATERIAL	MATL SPECIFICATION	VENDOR ~~CODE~~	CALC UNIT WT

GOVT

TECH DSGN

SCHEMATIC,
FLIGHT-QUALIFIED,
DOSIMETER SYSTEM
MODEL NDS-23 (APOLLO)

GD-NUCLEAR
GENERAL DYNAMICS | FORT WORTH

Wilson 6-7-65

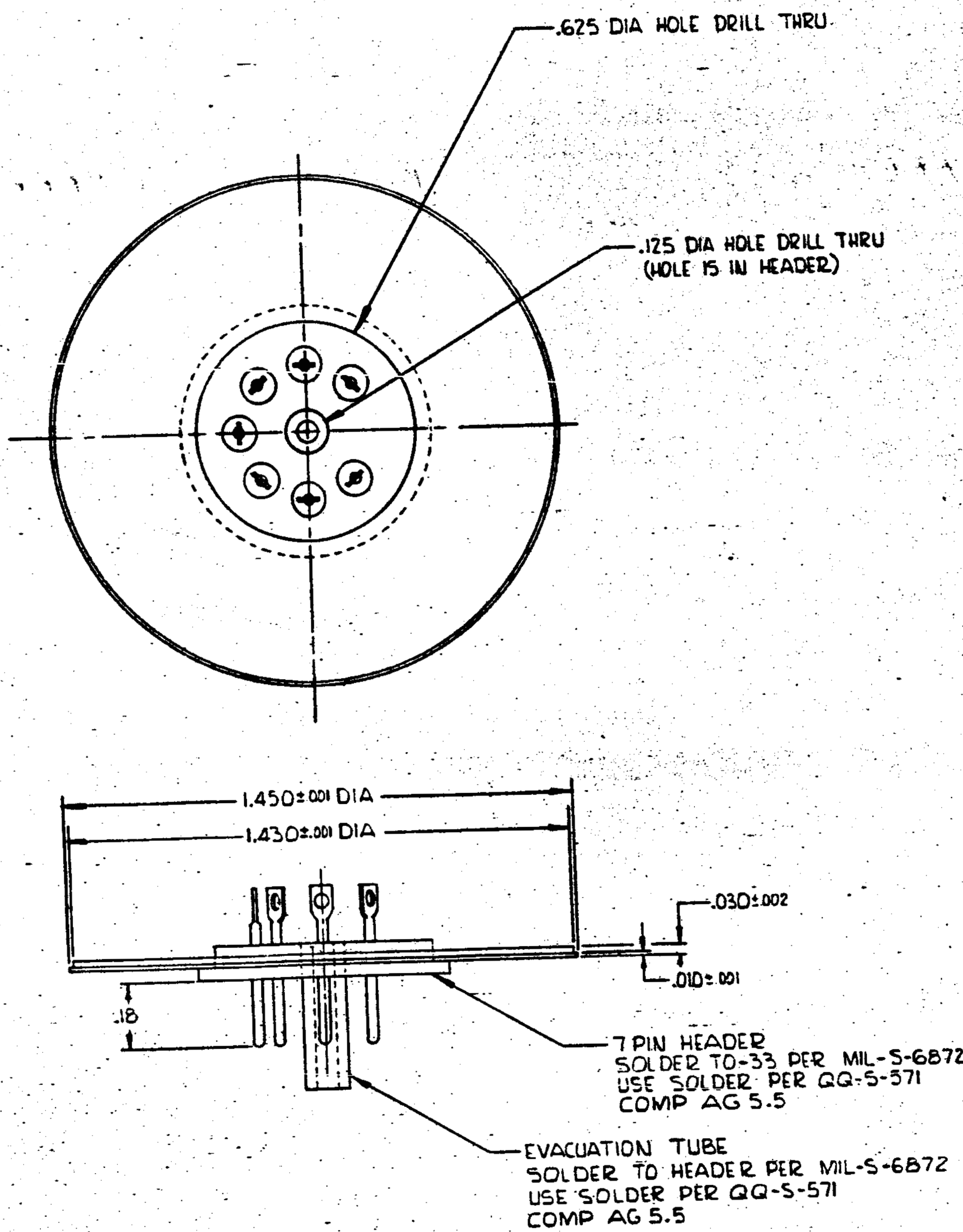
SCALE

DWG D SIZE | NLE 268

CODE 81755 | SH 1 | OF 1

DEPARTMENT 6
FW 181-9-62 BM & TITLE BLOCK

·4



DETAIL -33 ELECTROMETER COVER

SCALE: FOUR TIMES SIZE

NLM185 SH 3 OF 3

EFF ON	INC	SYM

HALF SIZE
OF

PART NO.	OPP DASH NO.	SHN	DESCRIPTION	STOCK S
			EVACUATION TUBE	.125 DIA X .03 WA
			HEADER 7 PIN	
		-33	ELECTROMETER COVER	1.5 DIA X .0

UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES

LINEAR TOL	X X	± .03
	X X X	± .010
ANGULAR TOL		± 0°30'

✓ ALL MACHINED SURFACES REF MIL-STD-10

GEN FINISH

HEAT TREAT

PROJ ENGR		
SR GR ENGR		
GR ENGR		
WEIGHTS		
STRESS		
CHECK		
DESIGN		
DRAFT	E. J. Wilson	8-75

REVISIONS DESCRIPTION	ZONE	DATE	APPROVAL

REPRODUCTION
ORIGINAL

X.4.. COPPER TUBE				
QQ-S-7636 (CRS)	CLASS 321			
ZE MATERIAL	MATL SPECIFICATION	ZONE	CALC UNIT WT	

GOVT
TECH DSGN

MACHINED PARTS,
ION CHAMBER,
FLIGHT — QUALIFIED
DOSIMETER SYSTEM
MODEL NDS-23 (APOLLO)

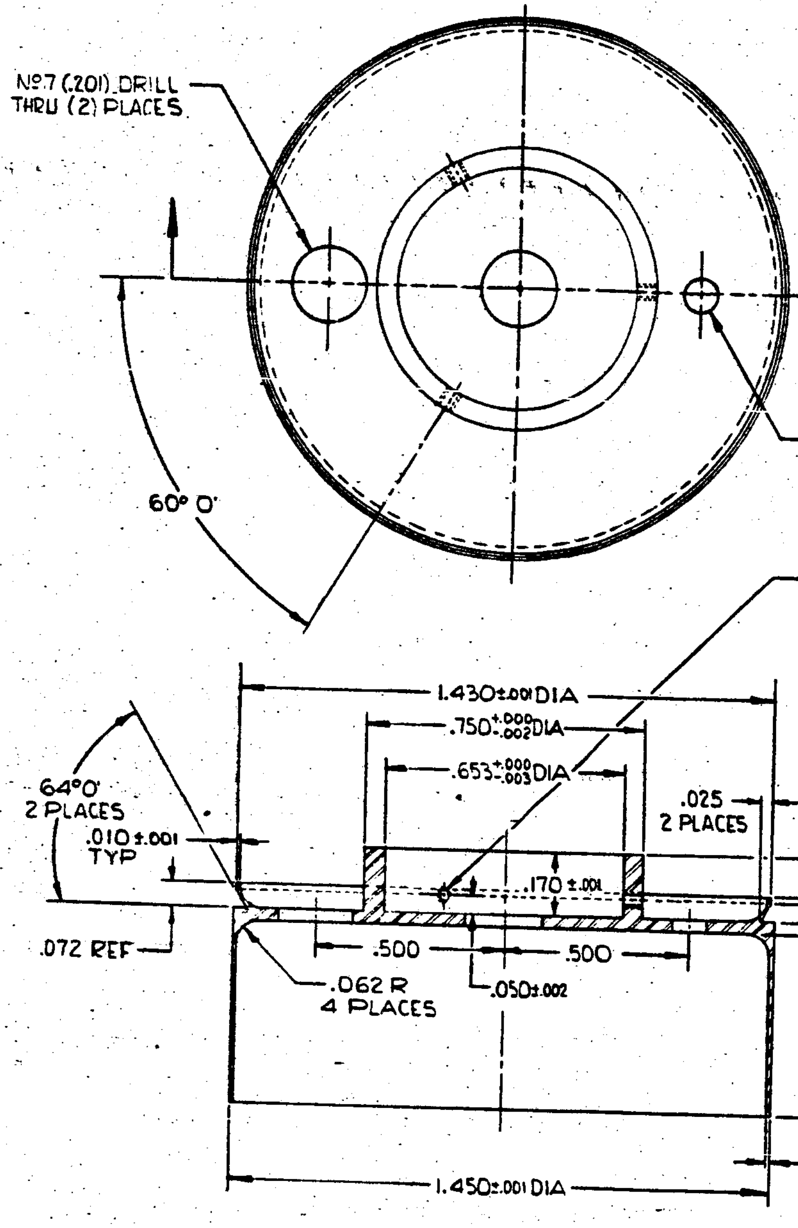
GD-NUCLEAR
GENERAL DYNAMICS | FORT WORTH

DWG SIZE D NLM185

SCALE AS NOTED | CODE 81755 | SH 3 OF 3

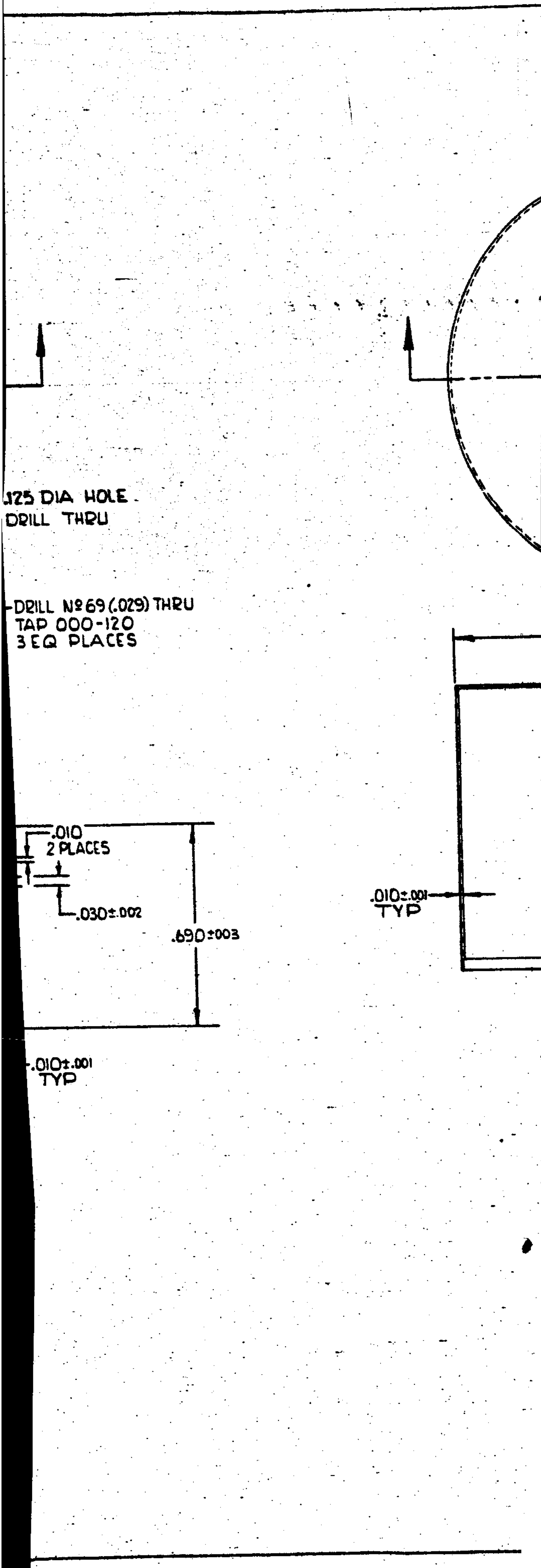
DEPARTMENT 5
FW 191-8-62 SH & TITLE BLOCK

3

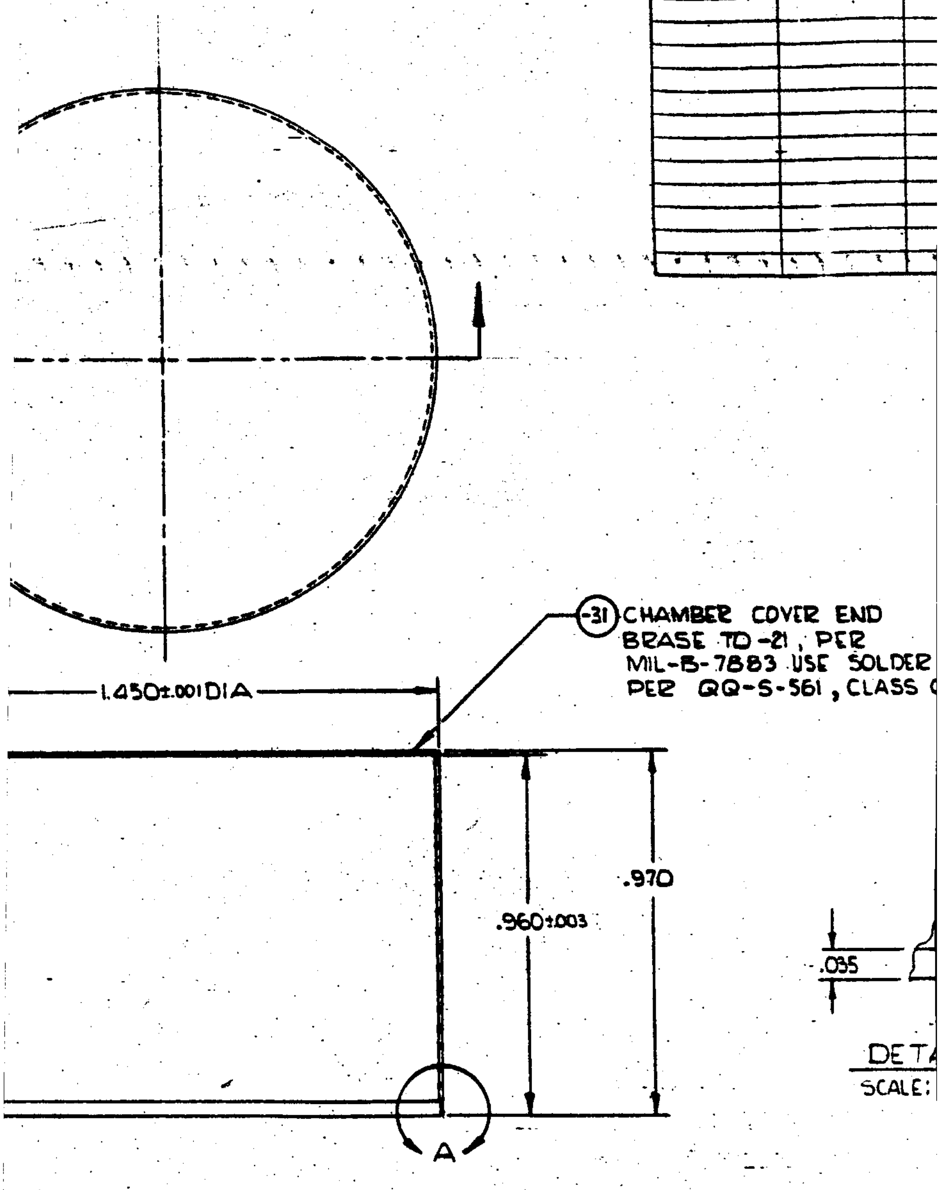


DETAIL -27 CHAMBER BASE

SCALE: FOUR TIMES SIZE


.125 DIA HOLE
DRILL THRU
DRILL Nº 69 (.029) THRU
TAP 000-120
3 EQ PLACES
.010
2 PLACES
.030±.002
.690±.003
.010±.001
TYP
.010±.001
TYP

EFF ON	INC	SYM



DETAIL -29 CHAMBER COVER
SCALE: FOUR TIMES SIZE

HALF SIZE
OF

PART NO.	OPP	SHN DASH NO.	DESCRIPTION	STOCK S
		-31	CHAMBER COVER END	.010THK X 1.
		-29	CHAMBER COVER	1.0 X 1.50
		-27	CHAMBER BASE	.75 X 1.50

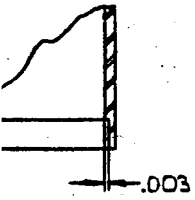
UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES		
LINEAR TOL	.XX	± .03
	.XXX	± .010
ANGULAR TOL		± 0°30'
✓ ALL MACHINED SURFACES REF MIL-STD-10		
GEN FINISH		
HEAT TREAT		

PROJ ENGR	
SR GR ENGR	
GR ENGR	
WEIGHTS	
STRESS	
CHECK	
DESIGN	
DRAFT	B.J. Wilson 1-22-6

B

REVISIONS			
DESCRIPTION	ZONE	DATE	APPROVAL

)



AIL "A"

TEN TIMES SIZE

REPRODUCTION

ORIGINAL

5 DIA	QQ-S-763b (CRS)	CLASS 321		
DIA	QQ-S-763b (CRS)	CLASS 321		
DIA	QQ-S-763b (CRS)	CLASS 321		
ZE	MATERIAL	MATL SPECIFICATION	ZONE	CALC UNIT WT

GOVT

TECH DSGN

MACHINED PARTS, ION CHAMBER, FLIGHT – QUALIFIED DOSIMETER SYSTEM, MODEL NDS-23 (APOLLO)

NUCLEAR

GENERAL DYNAMICS FORT WORTH

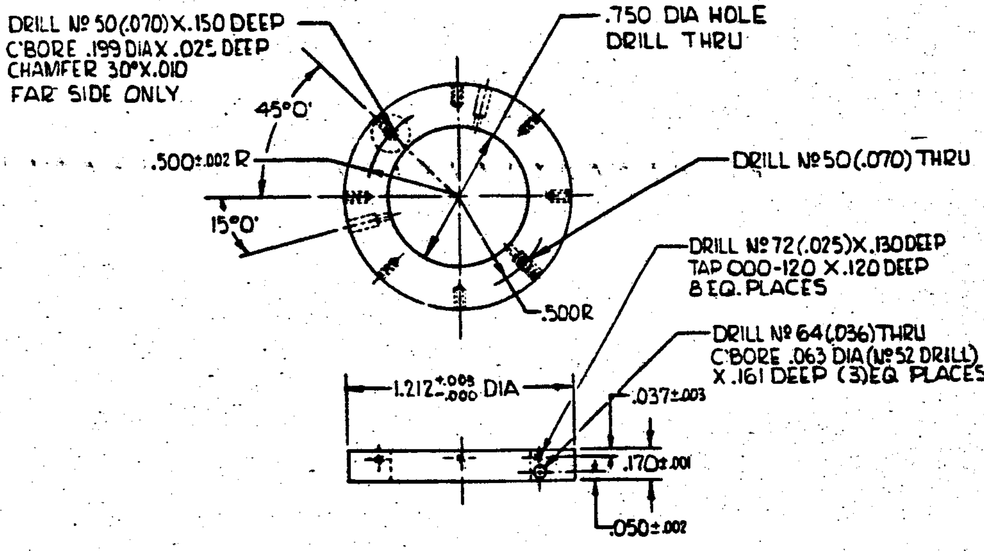
DWG SIZE	NLM185	
D	CODE 81755	SH 2 OF 3

SCALE AS NOTED

DEPARTMENT 6

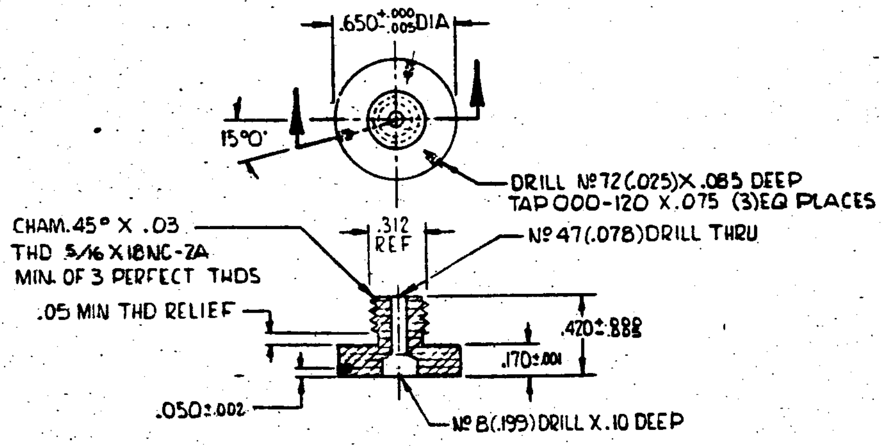
FW 181-9-62 BM & TITLE BLOCK

4



DETAIL-11 HIGH VOLTAGE INSULATOR

SCALE: TWICE SIZE



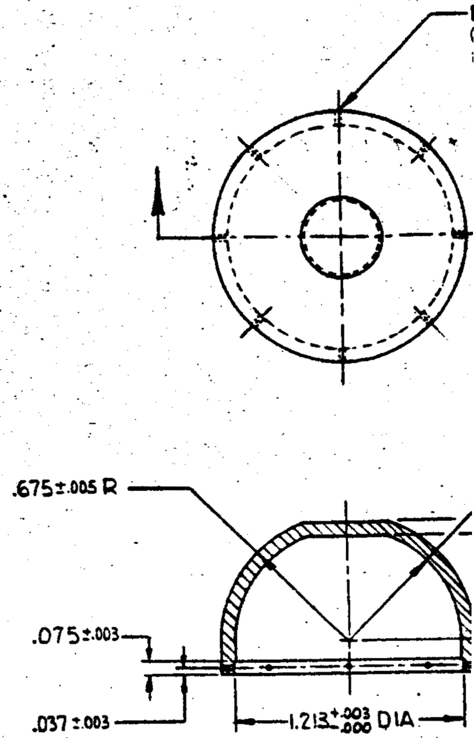
DETAIL-13 SIGNAL INSULATOR

SCALE: TWICE SIZE

NOTES:

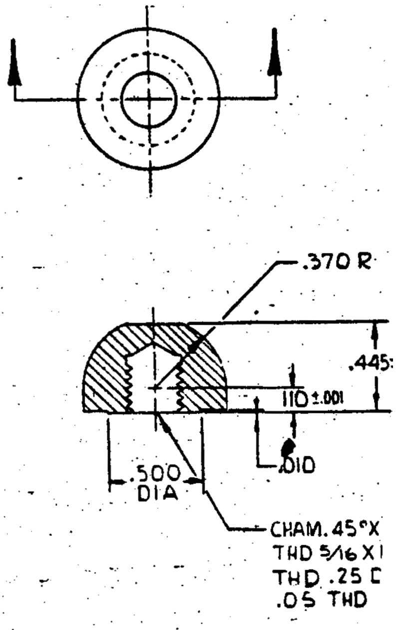
1. MADE FROM TISSUE EQUIVALENT PLASTIC, A-150 PURCHASED FROM, PHYSICAL SCIENCE LABORATORY, ST. PROCOPIUS COLLEGE LISLE, ILLINOIS.

2. MADE FROM № TISM-15-SM KOVAR SEAL PHYSICAL SCIENCES CORP. ARCADIA, CALIF.



DETAIL -15 HIGH VOLTAGE

SCALE: TWICE SIZE



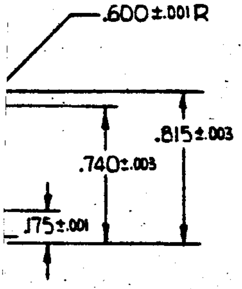
DETAIL -17 SIGNAL DON

SCALE: TWICE SIZE

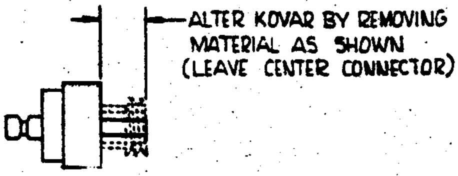
NLM185 SH 1 OF 3

EFF ON

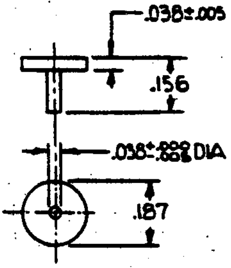
DRILL Nº 64(.036) THRU
C'SINK 100° X .040±.003 DIA
3 EQ. PLACES



DOME



DETAIL -19 CONNECTOR
SCALE: FOUR TIMES SIZE



DETAIL -21 SIGNAL CONTACT
SCALE: FOUR TIMES SIZE

HALF SIZE
OF

.003

03
NC-2B
EP WITH
ELIEF

E

PART NO.	OPP	SHN DASH NO.	DESCRIPTION
		-25	CONTACT SPRING
		-23	CONTACT SPRING
		-21	SIGNAL CONTACT
		-19	CONNECTOR
		-17	SIGNAL DOME
		-15	H.V. DOME
		-13	SIGNAL INSULATOR
		-11	H.V. INSULATOR

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES

LINEAR TOL	X X	.03
	X X X	.010
ANGULAR TOL		0°30'

ALL MACHINED SURFACES REF MIL-STD-10

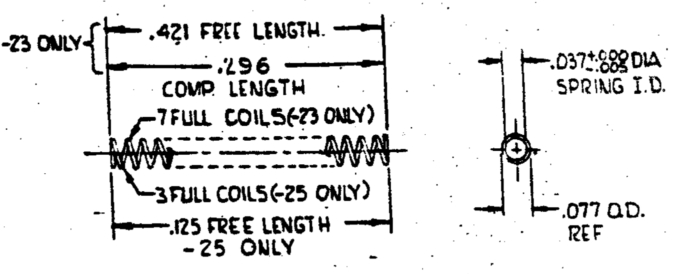
GEN FINISH

HEAT TREAT

PROJ ENGR
SR GR ENGR
GR ENGR
WEIGHTS
STRESS
CHECK
DESIGN
DRAFT

3

INC	SYM	REVISIONS DESCRIPTION	ZONE	DATE	APPROVAL



DETAIL-23 OR-25 CONTACT SPRING

SCALE: FOUR TIMES SIZE

STOCK SIZE	MATERIAL	MATL SPECIFICATION	ZONE	CALC UNIT WT
	.020 DIA PIANO WIRE			
	.020 DIA PIANO WIRE			
7 DIA X .16	COML GRADE BRASS			
	2			
DIA X .50	1			
5 DIA X .95	1			
DIA X .5	HI DENSITY POLYETHYLENE			
DIA X .20 THK	HI DENSITY POLYETHYLENE			

GOVT TECH DSGN

MACHINED PARTS, ION CHAMBER, FLIGHT – QUALIFIED DOSIMETER SYSTEM, MODEL NDS-23 (APOLLO)

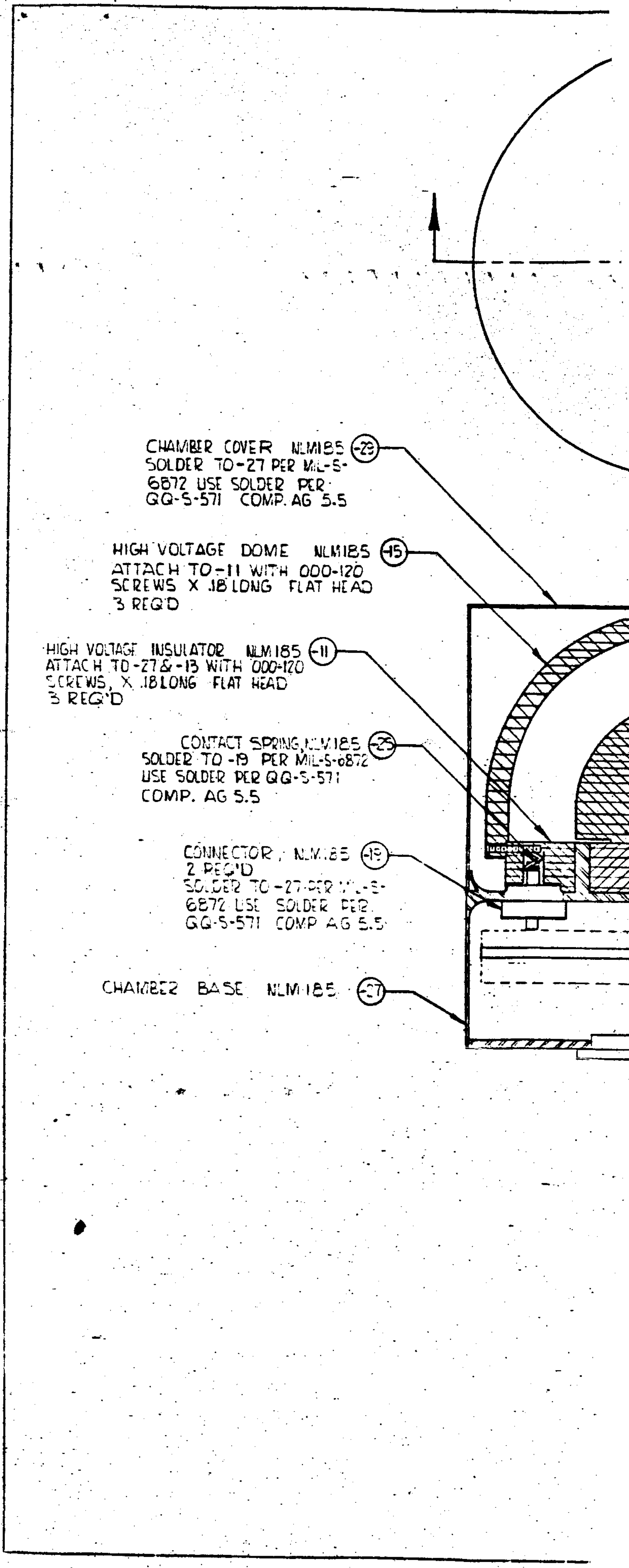
4-8-65 SCALE AS NOTED

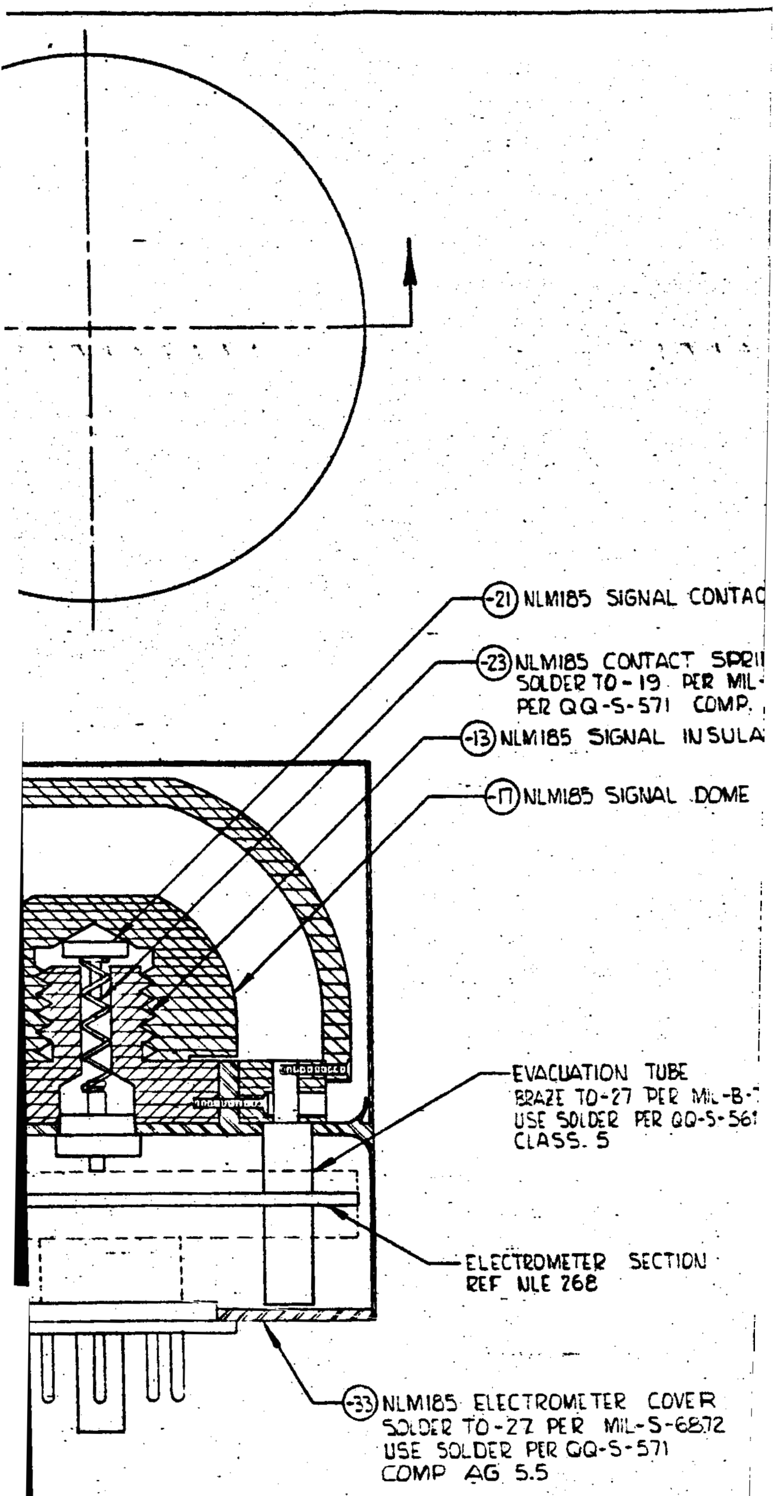
GD-NUCLEAR
GENERAL DYNAMICS | FORT WORTH

DWG SIZE D | NLM185 | CODE 81755 | SH 1 OF 3

DEPARTMENT 6
FW 181-9-62 BM & TITLE BLOCK

4


CHAMBER COVER NLM185 (-29)
SOLDER TO-27 PER MIL-S-6872 USE SOLDER PER QQ-S-571 COMP. AG 5.5
HIGH VOLTAGE DOME NLM185 (-15)
ATTACH TO-11 WITH 000-120 SCREWS X .18 LONG FLAT HEAD 3 REQ'D
HIGH VOLTAGE INSULATOR NLM185 (-11)
ATTACH TO-27 & -13 WITH 000-120 SCREWS, X .18 LONG FLAT HEAD 3 REQ'D
CONTACT SPRING, NLM185 (-25)
SOLDER TO -19 PER MIL-S-6872 USE SOLDER PER QQ-S-571 COMP. AG 5.5
CONNECTOR, NLM185 (-19)
2 REQ'D
SOLDER TO -27 PER MIL-S-6872 USE SOLDER PER QQ-S-571 COMP AG 5.5
CHAMBER BASE NLM185 (-27)



-21 NLM185 SIGNAL CONTAC
-23 NLM185 CONTACT SPRI
SOLDER TO-19 PER MIL-
PER QQ-S-571 COMP.
-13 NLM185 SIGNAL INSULA
-17 NLM185 SIGNAL DOME
EVACUATION TUBE
BRAZE TO-27 PER MIL-B-
USE SOLDER PER QQ-S-56
CLASS. 5
ELECTROMETER SECTION
REF NLE 268
-33 NLM185 ELECTROMETER COVER
SOLDER TO-27 PER MIL-S-6872
USE SOLDER PER QQ-S-571
COMP AG 5.5

2

NLM187 SH 1 OF 1

EFF ON	INC

T

G
S-6872 USE SOLDER
AG 5.5
TOR

HALF S

583

			6	000-120		SCREW, FLAT HD	.18 LONG
			1			ELECTROMETER SECTION	
			1			EVACUATION TUBE	.125 DIA X .0
			1	NLM185 -33		ELECTROMETER	COVER
			1	-29		CHAMBER COVER	
			1	-27		CHAMBER BASE	
			1	-25		CONTACT SPRING	
			1	-23		CONTACT SPRING	
			1	-21		SIGNAL CONTACT	
			2	-19		CONNECTOR	
			1	-17		SIGNAL DOME	
			1	-15		HIGH VOLTAGE DOME	
			1	-13		SIGNAL INSULATOR	
			1	NLM185 -11		HIGH VOLTAGE INSULATOR	
REQ'D PER ASSY			B/N	PART NO.	OPP SHN DASH NO	DESCRIPTION	STOCK

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
LINEAR TOL .XX ± .03
.XXX ± .010
ANGULAR TOL ± 0°30'
ALL MACHINED SURFACES REF MIL-STD-10 ✓
GEN FINISH
HEAT TREAT

PROJ ENGR
SR GR ENGR
GR ENGR
WEIGHTS
STRESS
CHECK
DESIGN
DRAFT B.J. Nilson

3

REVISIONS				
SYM	DESCRIPTION	ZONE	DATE	APPROVAL

IZE REPRODUCTION
OF ORIGINAL

3WALL X .50 LO...	COPPER TUBE			
SIZE	MATERIAL	MATL SPECIFICATION	ZONE	CALC UNIT WT

GOVT	
TECH DSGN	
ASSEMBLY, IONIZATION - CHAMBER, FLIGHT-QUALIFIED DOSIMETER SYSTEM	GD-NUCLEAR GENERAL DYNAMICS | FORT WORTH
MODEL NDS-23 (APOLLO)	DWG SIZE D | NLM187
SCALE FULL [illegible] SIZE	CODE 81755 | SH 1 OF 1

DEPARTMENT 6
FW 181-9-62 SM & TITLE BLOCK

4

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